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ON THE SEVERAL EFFICIENCIES OF THE STEAM ENGINE, AND ON THE CONDITIONS OF MAXIMUM ECONOMY.

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SECTION I.—METHODS AND PRINCIPLES.

1. The Several Efficiencies of the Steam Engine.

In the design of the Steam Engine, the Mechanical Engineer has frequent occasion to solve certain problems relating to its economical performance, and especially to determine what proportions of engine and boiler are best adapted to give maximum economy of fuel or of money under certain conditions precisely defined in advance. Such problems may usually be solved by the determination of the Ratio of Expansion producing Maximum Economy under the given conditions. The methods proposed by the writer for the solution of these problems form the subject of this paper.

Several problems of this character may be classed together, all of which relate to one or another of the "Several Efficiencies of the Steam Engine," as the writer has called them.

These "Efficiencies" are:

(1) *The Efficiency of Fluid.*—This is measured by the ratio of work done by the working substance to the mechanical equivalent of the heat expended on it. In the perfect engine this efficiency is measured by the quantity $\frac{\tau_1 - \tau_2}{\tau_1}$; the range of temperature worked through, divided by the maximum, initial, absolute temperature of the fluid entering the cylinder of the engine. In real engines, great losses occur by incomplete expansion and by direct transfer of heat from induction to exhaust without production of work.

(2) *The Efficiency of the Machine.*—This is measured by the ratio of the quantity of work transmitted from the engine to the "machinery of transmission" to the work done upon the piston by the working fluid.

(3) In some cases the product of the efficiency of the fluid by the efficiency of the machine is called the *Efficiency of the Engine* or of the System.

(4) *The Efficiency of the Furnace* is the ratio of quantity of heat transferred to the working substance to that developed by the fuel.

(5) The *Total Efficiency of the Apparatus, or of Plant,* as the writer would term it, is the product of these several partial efficiencies, and is the fraction of the total calorific power of fuel which is delivered to the machinery of transmission as mechanical energy.

(6) *The Efficiency of Capital,* or the Commercial Efficiency of Steam Machinery, is measured by the amount of capital employed, or of the total running expenses per unit of a given power required and obtained; *i. e.*, it determines how small a sum will provide a given amount of power and *what size of engine must be selected for the given work.*

Each of the above efficiencies is made a maximum by a set of conditions the determination of which constitutes an important problem in the Science of Engineering. Each must be solved, and in a certain definite order, before the engineer can feel perfectly confident of full success in the application of steam power to any given case. The determination of the efficiency of fluid is included in the problem relating to efficiency of engine, and this and all other efficiencies are included in the last—the Efficiency of Capital—which cannot be exactly determined unless they are first ascertained.

(7) In addition to the above, another problem may present itself to the user of power, although seldom to the designer, or to any one

proposing to purchase a steam engine—the determination of the maximum economy of a given plant; *i. e.*, how the most work may be obtained for a dollar from a given engine already constructed. This is entirely a different problem from (6); its solution leads to very different results, and does not usually, if ever, determine maximum commercial efficiency, as will be seen later. Here, then, the problem relates to what may be called the "*Maximum Commercial Efficiency of a given Plant.*"

(8) It may, finally, be necessary to determine still another question: "*What is the Maximum Amount of Power that can be profitably obtained from a Given Plant?* This is a more commonly familiar problem than the last and of more direct and practical importance in most cases.

2. Furnace and Boiler Efficiencies.

The first case which naturally presents itself to the designing engineer, that relating to *Efficiency of Furnace, or of Boiler,* has been frequently studied, and is well understood. To secure maximum efficiency, the engineer must provide for:

(1) Complete combination of fuel and oxygen without excess of air supply.

(2) Rapid and concentrated combustion.

(3) Rapid and general circulation of the heating-gases and of the heated fluid.

(4) Ample area of well-arranged heating surface to transfer heat from the furnace gas to the water.

In the case of a steam boiler, efficiency is a function of area of heating surface and of quantity of fuel burned on the given area of grate surface. Rankine deduces the expression

$$\frac{E}{E'} = \frac{B}{1 + \frac{AF}{S}}$$

in which $\frac{E}{E'}$ is the ratio of water evaporated per pound of fuel to that which would be evaporated were the whole calorific power of the fuel utilized. Then

$$E = \frac{BE'}{1 + \frac{AF}{S}}; \quad S = \frac{FA}{\frac{BE'}{E} - 1};$$

S is the area of heating surface per unit of area of grate and F the

number of pounds of fuel burned per hour per square foot of grate. The constant B is, for bituminous coal, burned in good boilers about 1; A varies from 0·3 with forced draught to 0·5 with chimney draught, probably varying nearly as the square of the weight of air supplied the fuels. Where a forced circulation has been obtained, the writer has found a lower value even than 0·3. In experiments with anthracite coal he has usually obtained a lower value of B than is given above, varying from 0·85 to 0·90.

The engineer in using the above formula usually decides what efficiency he can afford to pay for and then obtains the value of S and thus determines the size and weight of his boiler; he rarely makes $\frac{E}{E'}$ exceed 0·75 and will often find it best to accept a much lower value in order to obtain maximum commercial efficiency. This case should be treated similarly to that relating to the commercial efficiency of engines described hereafter at some length, thus:

It will be found that the maximum commercial efficiency of boiler—*i. e.*, the proportion of heating surface to grate surface or to fuel burned on the grate per hour which gives the required amount of steam at least total expenditure—is determined by the equations,

$$S = A'F\sqrt{R}, \quad \frac{S}{F} = A'\sqrt{R}$$

in which S is the area of heating surface per unit of area of grate; F is the weight of fuel burned on that unit of area; A is a coefficient varying from 0·5 with boilers of quick or forced draught and good circulation to 0·7 with boilers having sluggish draught and a less perfect circulation; R is the quotient obtained by dividing the sum of all annual expenses, dependent on amount of fuel burned, reckoned per pound of fuel and per square foot of grate, by the sum of all the annual expenses per square foot of heating surface, so far as they are dependent upon size and character of boiler; as interest, repairs and depreciation. *E. G.*—For a usual case in marine practice, $A' = 0{\cdot}5$; $F = 12$; $R = 26$; $S = 30$. For a case of continuous operation of boiler, as in a flour mill, $A' = 0{\cdot}6$; $F = 10$; $R = 25$; $S = 30$. For certain cases of occasional use, as in a steam yacht, $A' = 0{\cdot}7$; $F = 12$; $R = 10$; $S = 28$; $A' = 0{\cdot}6$; $F = 10$; $R = 8$; $S = 17$.

R sometimes becomes as great as 50 in ordinary practice when fuel is expensive.

The proportions of boilers of any given class are seen to be dependent solely upon the quality of fuel burned, and the relation existing between the two classes of expenses—those of operation and those of maintenance.

When the boiler is once constructed and set, it is sometimes found possible to use profitably a larger quantity of steam than it was designed to furnish, and it may become a matter of interest, if not of importance, to determine what amount of steam will give the largest quantity per dollar of total running expense. In such a case the boiler is worked with a more rapid draught, and more fuel is burned on the grate, other conditions affecting efficiency being constant except as dependent upon the quantity, F, which now becomes the independent variable. The total cost of steam now becomes the sum of all expenses, constant and variable, and, calling K the annual cost of all items invariable with variation of quantity of coal burned, and $k = \frac{K}{G}$, this cost divided by area of the grate, it will be found that the "Maximum Commercial Efficiency of Plant," as the writer calls it, will be obtained when

$$F = \sqrt{\frac{k\,S + D\,S^2}{A\,C}}$$

when D is the annual cost per unit of S, as before, of items variable with S; and C is the annual cost, as before, per unit of F, of items variable with F. The boiler may often be profitably forced still further, until the cost of working no longer allows a profit on the steam made and used; but this limit may be reached either within or beyond the value of F, just deduced; it is found, when, if k, C and D measure the cost of constant items of expense per unit of grate area of variable expenses for fuel and for boiler, and M is the *value* of steam, per unit of weight,

$$k\,G + C\,F\,G + D\,G\,S = M\,F\,G\,E'$$

i. e., when the sum of all expenses becomes equal to the total *value* of the steam made. The analysis covering this case will be given in a later paper.

3. *Efficiency of Engine.*

The efficiency of engine has been often studied by authorities accepted as a standard, but almost invariably as a problem in thermodynamids, simply; and the losses of heat occurring in consequence of

the working of steam in a cylinder composed of a good conductor of heat have been left unnoted although frequently the most important of all the expenditures of heat taking place in the engine. Mr. D. K. Clark discovered this phenomenon in 1851 and described it clearly in his papers and late publications. Professor Rankine noted this method of waste and describes the phenomenon fully as early as 1859,* but neither he nor any other writer, Clark excepted, for many years, seems to have realized the extent and importance of this loss in all engines.† Prof. Cotterill alone, of all authors known to the writer, has treated this part of the problem of steam engine efficiency in a manner that is at all practically satisfactory to the engineer.‡

The writer has endeavored in an earlier paper § to show what conditions determine maximum efficiency of fluid and of engine. In a non-conducting cylinder the maximum Efficiency of Fluid would be secured if the ratio of expansion were made nearly equal to the quotient of initial by back pressure; $r^n = \frac{p_1}{p_3} = \frac{p_1}{p_2}$, while the efficiency of engine would be made a maximum when the ratio is made equal to the quotient of initial pressure by the sum of all useless resistance; $r^n = \frac{p_1}{p_b} = \frac{p_1}{p_2}$. When, however, as is always the case in practice, the steam is worked in a metallic cylinder, the best ratio of expansion is made very much smaller, and the efficiency of the engine is greatly reduced by cylinder condensation and reëvaporation, which produce a serious waste of heat. The extent of this modification has been indicated by the writer, and an attempt has been made to determine by simple method based on experiment and observation what are the usually best ratios of expansion and what the least probable quantities of steam and of fuel demanded per hour and per horse-power, at maximum efficiency by the principal standard types of engine.

In a still later paper‖ the writer has exhibited at greater length the differences in the behavior of steam expanding in a non-conducting

* Steam Engine, etc., § 286; par. 2.

† Proc. Inst. Mech. Engrs., 1852; Railway Machinery, 1855; Handbook for Mech. Engrs., 1877.

‡ The Steam Engine considered as a Heat Engine; J. H. Cotterill, London and New York, 1878

§ On the Ratio of Expansion at Maximum Efficiency.—*Trans. Am. Soc. Mech. Engrs.*, 1881.—*Journal Franklin Institute*, May, 1881.

‖ On the behavior of Steam in the Steam Engine, etc.—*Jour. Frank. Inst.*, Feb., 1881.

vessel, and in the metal cylinder of the steam engine, and has shown how to determine and construct true "Curves of Efficiency" for actual engines, exhibiting the charater of this newly discovered curve, and its functions. It was shown that the total loss of efficiency of work, or of pressure, due to cylinder condensation, may be allowed for by taking for its value the expression $a\,r^m$, in which a is constant dependent upon the state of the steam before expansion, r is the rate of expansion, and ^{m} is an exponent dependent upon the method of variation of the proportions of the mixture of steam and water as expansion progresses.

The useful work per stroke is a maximum, and the ratio of expansion at maximum efficiency of engine is found when the latter is of such value as to satisfy the equation

$$r^{-n} - a\,r^{m-n} = \frac{p_b}{p_1}, \text{ nearly,}$$

and when, if c is the "cut-off"

$$c^n - a\,c^{n-m} = \frac{p_b}{p_1}, \text{ nearly.}$$

The value of the constant a varies from 0·1 to 0·2, in good engines, according to quality of steam supplied, and ^{m} may be taken at 0 in the best cases of well designed compound engines, and as rising to 0·5 in unjacketed single cylinder engines; n is the exponent in the equation of the expansion line.

The probable minimum expenditure of steam per hour and per horse-power were also given as follows in the first of this series of papers:

Probable Minimum Weights of Steam per Hour per Horse-power.

r_e	W Pounds.	W_m Kilos.	r	W Pounds.	W_m Kilos.	r_e	W Pounds.	W_m Kilos.
3	32	15	8	20	9	13	17	8
4	27	12	9	19	9	14	16	7
5	25	11	10	19	9	16	16	7
6	22	11	11	18	9	20	15	7
7	20	9	12	17	8	25	15	7

Studying these modifying conditions as observed in practice, the best rates of expansion for maximum duty r_e^1, for several well-known and typical classes of engines are taken by the writer thus:

Probable Terminal Pressures and Rates of Expansion at Maximum Efficiency.

Case.	Initial Pressures. *Absolute.*		Speed of Piston.		Single Cylinders. Class I.—Non-condensing. Class II.—Condensing.										Compound (N=2) Condensing. Class III.								
					Unjacketed.			Jacketed.			Unjacketed.			Jacketed.			Sides jacketed.			Heads and sides jacketed.			Heads and sides jacketed with efficient superheating.		
	$p_i=p_v$						r_e^1	$p_i=p_v$		r_e^1	$p_i=p_v=p_c$		r_e^1	$p_i=p_v=p_c$		r_e^1	$p_i=p_v=p_c$		r_e^1	$p_i=p_v=p_c$		r_e^1	$p_i=p_v=p_b+p_f$		r_e^1
	P_1	P_m	V	V_m	Lbs. on sq. in.	Kilos on sq. cm.		Lbs. on sq. in.	Kilos on sq. cm.		Lbs. on sq. in.	Kilos on sq. cm.		Lbs. on sq. in.	Kilos on sq. cm.		Lbs. on sq. in.	Kilos on sq. cm.		Lbs. on sq. in.	Kilos on sq. cm.		Lbs. on sq. in.	Kilos on sq. cm.	
I.	40	2·8	400	122	20	1·4	2·0	20	1·4	2·0	16	1·1	2·5	13	·9	3·0	9	·6	4·5	7½	·5	5	7½	·5	5
			625	185	20	1·4	2·0	20	1·4	2·0	13	·9	3·0	13	·9	3·0	9	·6	4·5	7½	·5	5	7½	·5	5
II.	60	4·2	400	122	20	1·4	3·0	20	1·4	3·0	20	1·4	3·0	15	1·1	4·0	11	·8	5·5	8	·6	7·5	7½	·5	8
			625	185	20	1·4	3·0	20	1·4	3·0	15	1·1	4·0	15	1·1	4·0	11	·8	5·5	8	·6	7·5	7½	·5	8
III.	80	5·6	400	122	23	1·6	3·5	20	1·4	4·0	23	1·6	3·5	18	1·3	4·5	13	·9	6·5	3	·6	9	7½	·5	11
			625	185	20	1·4	4·0	20	1·4	4·0	18	1·3	4·5	18	1·3	4·5	13	·9	6·5	9	·6	9	7½	·5	11
IV.	100	7·0	400	122	25	1·8	4·0	20	1·4	5·0	25	1·8	5	20	1·4	5·0	14	1·1	7·0	10	·7	10	7½	·5	13
			625	185	20	1·4	5·0	20	1·4	5·0	20	1·4	5	20	1·4	5·0	14	1·1	7·0	10	·7	10	7½	·5	13
V.	120	8·4	400	122	27	1·9	4·5	22	1·5	5·5	27	1·9	4·5	22	1·5	5·5	16	1·1	7·5	11	·8	10·5	7½	·5	17
			625	185	22	1·5	5·5	22	1·5	5·5	22	1·5	5·5	22	1·8	5·5	16	1·1	6·5	11	·8	10·5	7½	·5	17
VI.	150	10·5	400	122	30	2·1	5·0	25	1·8	6	30	2·1	5·0	25	1·3	6·0	18	1·3	8·5	12·5	·9	12	7½	·5	20
			625	185	25	1·8	6·0	25	1·8	6	25	1·8	6·0	25	1·1	6·0	18	1·3	8·5	12·5	·9	12	7½	·5	20
VII.	200	14.1	400	122	36	2·6	5·5	29	2·1	7	36	2·5	5·5	29	2·1	7·0	20	1·4	10·0	14	1·0	14	7½	·5	27
			625	185	29	2·1	7·0	20	2·1	7	29	2·1	7·0	29	2·1	7·0	20	1·4	10·0	14	1·0	14	7½	·5	27

The terminal pressure $p_i=p_v$ is taken as equal to p_b+p_f the sum of back pressure and frictional resistance in non-condensing engines with low steam, and in highly superheated steam engines.

Deduct 14·7 lbs. per sq. in. = 1 kg. per sq. cm. to obtain gauge pressures. Hyperbolic expansion is here assumed.

P_1 P_m are pressures in British and Metric measures, V_1 V_m are velocities in the same measure.

Taking the probable minimum expenditure of coal per hour and per horse-power at *one-ninth* the weight of steam demanded, we get, at the ratio of expansion giving a minimum cost of steam, the following:

Probable Minimum Weights of Coal per Horse-power per Hour.

r_e	W' Pounds.	W'_m Kilos.	r_e	W' Pounds.	W'_m Kilos.	r_e	W' Pounds.	W'_m Kilos.
3	3·5	1·6	8	2·2	1·0	13	1·9	0·9
4	3·0	1·4	9	2·1	1·0	14	1·8	0·8
5	2·8	1·3	10	2·1	1·0	16	1·8	0·8
6	2·3	1·1	11	2·0	0·9	20	1·7	0·8
7	2·2	1·1	12	1·9	0·9	25	1·7	0.8

For cases in which the boiler gives an evaporation of ten pounds of water per pound of coal we may get ten per cent. better figures.

The Efficiency of the Apparatus is the product of efficiency of furnace and boiler, the efficiency of engine and the efficiency of mechanism of transmission. It is made a maximum when each of its factors is a maximum.

4. Efficiency of Capital.

The Efficiency of Capital, Case 6, is the most interesting of this series of problems of maximum efficiency, and its solution, by a practically correct method giving reliable results accordant with experience has been, by some engineers, regarded as one of the most important of problems now demanding the attention of the engineer. It is this problem which is proposed as the principal subject of the present paper.* In studying the efficiency of capital, it is first necessary to consider the elements of cost of power. The problem may be stated thus: *Given* the quantity of power required, to determine what ratio of expansion and what size of engine will give that power at minimum cost.

To solve this problem the engineer must know the cost of the engines, boilers and appurtenances and all items of running expense.

* This problem was first enunciated by Rankine, and solved for the case of the non-conducting cylinder.—*Vide Phil. Mag.*, 1854; *Miscell. Papers*, p. 295.

Then making the sum of both items of variable annual expense—those variable with size of engine and those variable with quantity of steam demanded—a minimum, the sum of these items and of all invariable expenses, *i. e.*, of the total running expense, becomes a minimum, and the problem is solved. A knowledge of these conditions and of all other expenses, constant as well as variable, is also essential to the treatment of Case 7, which may be thus stated :*

Given the size, power and all items of cost, and running expenses of a known plant of steam machinery, to determine what method of working the steam, *i. e.*, what ratio of expansion will give most work for a dollar of total expense of operation.

Since the economy of fuel and steam demands the use of a large engine, working steam with a considerable expansion and gives reduced size and weight of boiler, it is evident that the first of these two problems is to be solved by determining what proportion of engine and boiler will be cheapest when summed up at the end of the life of the plant; this is settled when the ratio of expansion at maximum commercial efficiency is known, since the best size of engine and boiler is then fixed. The work may be done either by a large engine and a small boiler, or by a smaller engine supplied with more steam by larger boilers.

The second problem—Case 7—is solved by determining what degree of expansion will give most power from an engine and boiler already installed, at least cost per horse-power. The first problem contains, as elements, all items of cost variable with change of proportions of engines and boilers capable of doing the same given quantity of work. The second problem considers every item of expense, and the amount of power is a variable quantity. Both problems require the study of the costs of steam power and the determination of the way in which each is related to total expense and the manner in which each varies with variation of the variable quantities in either case.

If, therefore, we have given a certain annual invariable expense of operation, certain additional expenses variable with size of engine, and therefore with the ratio of expansion adopted, and certain other additional expenses variable with quantity of steam demanded and with size of boiler needed, and thus also dependent upon the ratio of

* First treated, so far as the writer is aware, by Messrs. Wolff and Denton, who solved it for the ideal case.—*Trans. Am. Society Mech. Engrs.*, 1881; *American Engineer*, 1881.

expansion at which that steam is used, we may call the two latter quantities, respectively, $f^{i}(r)$ and $f^{ii}(r)$ while the constant part may be called C. Then the total annual expense is $f^{i}(r)+f^{ii}(r)+C$, which is a minimum when the variable part, $f^{i}(r)+f^{ii}(r)=f(r)$ is a minimum, and this is a minimum when its ratio to work done, $F(r)$, is a minimum, *i. e.*, when $\frac{f(r)}{F(r)}$ is a minimum, or $d\,\frac{f(r)}{F(r)} \div dr = 0$. The value of r which satisfies this condition gives Maximum Commercial Efficiency.

The determination of the value of r which makes $\frac{f(r)+C}{F(r)}$ a minimum, gives the solution of Case 7.

Case 8 is solved by determining at what ratio of expansion the cost of power becomes equal to the market value of the power, less a paying profit.

The Annual Cost of Steam Power consists:

(1) Of certain expenses, which, in any given case, are usually invariable, whether the work is done by a large engine with high ratio of expansion and small boilers, or with a smaller engine working at a low rate of expansion and with larger boilers. These are usually: rent of building or interest on cost, taxes, repairs, etc., etc., of structure and location, the engineer's salary and sometimes all or part of the fireman's or stoker's, also sundry minor expenses or a part of each of other expenses, which as a whole are variable. Both of the latter classes may usually be neglected in solving the problems here first considered.

(2) The interest on first cost of engine in place, the cost of repairs, and a sum which measures the depreciation in value of the machine due to its natural wear, or to its decreasing value in presence of changes that finally compel the substitution for it of an improved engine. Oil, waste and other engineer's stores fall under this head. These items are variable with size and style of engine.

(3) The expenses of supplying the engine with steam. These are:

(*a*) The cost on fuel account of the steam supplied and which includes also the cost of steam condensed *en route* to the engines and wasted by cylinder condensation and leakage, as well as that actually utilized. This total quantity of steam greatly exceeds that actually used in the production of power by simple transformation of heat

energy. This item varies with the efficiency of engine and size of boiler demanded.

(*b*) The account of interest on cost of boilers in place and of their appurtenances, rent of boiler-room, depreciation, repairs and insurance; which latter account is wholly chargeable to boilers. This is also variable with size of boilers.

(*c*) Cost of attendance in excess of the costs included in the constant quantity in item (1) and variable with size of boiler or quantity of steam demanded.

The salary of the engineer is usually not chargeable to either engine or boiler; his position is one of supervision over the whole apparatus, and a good engineer usually keeps the closest watch over the boilers. The engine can usually be trusted, much of the time, to take care of itself. With small engines, the engineer is also the fireman. With large engines, the number of regular firemen, or, at least the number in excess of one attendant may be taken as proportional to the quantity of steam demanded when working at ordinary power, and with very large marine engines, the same remark will apply to engine-room attendance.

In recapitulation:

(1) In working up this account, it will be most convenient, as will be presently seen, to refer all costs to volume of cylinder and to so express variable quantities that they may enter our equations in terms of the ratio of expansion, which ratio is to be taken as hereafter shown, as an independent variable upon which all other variable quantities are made dependent. We will enter all constant quantities as so many dollars of *annual* expense; the total, invariable expense will then be A, where A includes all such expenses, whether chargeable to the engines or boilers, or to both.

(2) The cost of an engine varies according to no definite rule, and differs greatly with type of engine, kind of valve gear, character of work and value of material and labor, both at the manufactory and at the place of installation. With certain standard forms of engine, however, it is found that the cost to the builder may be reckoned as very nearly proportional to volume of steam-cylinder, and his prices may be fixed on that basis. The cost of transportation, other things being equal, may often be similarly estimated, as may expenditures for repairs, engineer's supplies, etc., although these items are less exactly determinable.

It is here assumed that interest on cost of engine in place, depreciation, repairs and all other expenses variable with size of engine, are to be reckoned per cubic foot of cylinder. This method is, in the opinion of the writer, more nearly correct than any other system of charging to this account that he has considered, and its probable error will be certainly unimportant for the small range met with in the usual case here studied.

(3) The cost of steam supplied to the engine, exclusive of the constant quantity entered in (1) may be safely reckoned as a certain number of dollars per pound or per cubic foot of steam worked in the cylinder.

The weight of steam supplied for the performance of work—when the weight per cubic foot of steam at the given pressure, p, is w, and its volume is $v_1 = v_2 \div r$, where r is the "real" ratio of expansion, is $w v_1 = \frac{w v_2}{r}$; its cost per cubic foot of steam cylinder is $\frac{C w v_1}{v_2} = \frac{C w}{r}$, and its total cost per year is $2 R C w v_1 = 2 R C \frac{w v_2}{r}$, where R is the number of revolutions made by the engine per annum.

To this weight is to be added steam wasted by cylinder condensation, leakage and by conduction and radiation from engine and boiler. This last quantity varies greatly with kind of engine, speed of piston and other circumstances more or less under control of the builder or engineer. It sometimes even amounts to several times as much as the steam actually utilized.

It may be allowed for by multiplying the last item by a factor greater than unity.

5. *Theory of the Efficiencies of the Perfect Ideal Steam Engine.*

When, as is perhaps sometimes allowable, if treating of the best of modern engines, the variation of cylinder condensation with variation of the ratio of expansion may be neglected, the "Equation of Ideal Steam Engine Efficiencies," as the writer would call it, may be written:

$$V = \frac{1}{E^{iii}} = \frac{A r v_1 + B v_1}{2 R W_n} = \frac{A + B r^{-1}}{2 R \left(p_1 \frac{n r^{-1} - r^{-n}}{n-1} - p_b \right)}$$

Where V is the counter efficiency, and E^{iii} is the ratio of work done

to variable costs, and therefore in the sense adopted here, the efficiency. This becomes a minimum, and the best ratio of expansion is obtained when, r being made the independent variable,

$$A\,p_1\,\frac{n-n\,r^{1-n}}{n-1} - B\,(p_1 r^{-n} - p_b) = 0;\; r^{-n} - M\,\frac{n-n\,r^{1-n}}{n-1} = \frac{p_b}{p_1}$$

Here r has become r_e^{iii}. In these equations A is the total annual variable charge per cubic foot of cylinder on engine account, B is the annual cost of steam per cubic foot *filled* each stroke, and is measured by $2\,R\,w\,C$, when R is the number of revolutions of engine *per annum*, w the weight of a cubic foot of steam at the pressure p_1, and C its cost per pound, including all running expenses, in the boiler room, and $M = \frac{A}{B}$.

More explicitly: since this problem demands minimum cost of a known power and the Ratio of Expansion at Maximum Commercial Efficiency, we have

$$p_1 v_1 \frac{n - r^{1-n}}{n-1} - p_b r v_1 = \text{Constant} = W.$$

The variable cost will be, as before,

$$P = A r v_1 + B v_1,$$

which is to be a minimum. But from the equation of condition, above,

$$v_1 = \frac{W}{p_1 \dfrac{n - r^{1-n}}{n-1} - p_b r}.$$

Thence

$$u = \frac{M + r^{-1}}{n r^{-1} - r^{-n} - \dfrac{p_b}{p_1}(n-1)};$$

and the minimum is found, as above, when $\frac{du}{dr} = 0$; *i. e.*, when

$$r^{-n} - M\,\frac{n - n r^{1-n}}{n-1} = \frac{p_b}{p_1}.$$

The construction of the equation shows that, under the assumed conditions, this ratio of maximum commercial economy is not dependent on the size of engine; but small engines have a higher value of p_b than large engines, as they are usually more subject to cylinder condensation, and have greater back pressure and friction. They there-

fore require to be worked with somewhat less expansion than large engines.

Thus the solution of the problem determining the ratio of expansion r_e^{iii} at "Maximum Commercial Efficiency," or Efficiency of Capital, fixes that size of engine which, doing the required work, will do it at least cost. The sum of all variable expenses being here made a minimum, the total running expense, which includes all variable charges, also becomes the least possible, and the given work is done at least total annual cost.

To find the ratio of expansion at which the given engine will give the largest amount of work for the dollar, *i. e.*, to determine the "Ratio of Expansion r_e^{iv} at Maximum Efficiency of a Given Plant," we may use this same general equation. In this case, the size of the engine being fixed, the annual "cost of engine" becomes constant, and we write the equation in precisely the same form as before.

$$V = \frac{1}{E^{iv}} = \frac{A_1 r v_1 + B v_1}{2 R W_s}$$

making the symbol A_1 cover all annual expenses of the engine room, estimated per cubic foot of cylinder, including all the *constant* charges of attendance in the boiler room as well, while B only includes costs variable with the steam supply; V thus measures the ratio of total annual expenses of operation to work done. We thus obtain such a ratio of expansion that

$$r^{-n} - N \frac{n - n r^{1-n}}{n - 1} = \frac{p_b}{p_1}$$

when N is the ratio of the total expenses classed with engine cost to the "cost of full steam," as already taken, and r has become r_e^{iv}.

Again: making A and N equal zero in the general equation, and making p_b the sum of all useless resistances

$$r^{-n} = \frac{p_b}{p_1}$$

and $r = r_e^{ii}$, the ratio of expansion at "Maximum Efficiency of Engine."

Similarly, if p_3 is the back pressure in the steam cylinder

$$r^{-n} = \frac{p_3}{p_1}$$

and we have the ratio of expansion at "maximum efficiency of fluid," $r = r_e^{i}$.

In each case the expression obtained is derived, it will be noted, by making r the independent variable, and is independent of the actual size of the engine. Thus we determine, in each case, the ratio of efficiency which is correct under the assumed conditions for all engines of the class upon which our estimates are based.

We thus are able to *tabulate* the proper size of engine for assumed quantities of work, and the powers at which each engine, once set, will work with maximum efficiency, commercial or other, if the power can be utilized. Finally, comparing costs, it can be determined in any known case just when a change of engine will be financially advisable. But the above simple and beautiful method of treatment cannot be applied where cylinder condensation becomes a serious item; in fact, therefore, it is comparatively valueless for nearly all cases which come up in engineering practice.

A comparison of the quantities of steam demanded to supply an engine thermodynamically "perfect" with the actual quantities required by even the best engines exhibits so wide a difference that it becomes obvious that the determination of the efficiency of an engine and the solution of the questions involving those of expenditure of heat are not problems in thermodynamics simply. The mathematical theory of the steam engine is not yet in so satisfactory a state, and cannot be until the correct theory of this transfer of waste heat can be introduced into it—that the engineer can often use it in every-day office-work with much confidence, unless checked by direct experiment. Even where algebraic analysis is probably capable of giving approximat. results, few engineers will attempt to use it. For the latter case, however, Rankine's graphical treatment of the problem here studied is conveniently applicable, and by its use the engineer may easily solve such problems by a simple construction on his drawing board.

6. *Rankine's Diagram of Efficiency.*

In illustration: Suppose an engine, of one cubic foot capacity, in operation, expanding steam adiabatically, its cylinder and piston being perfectly impervious to heat, and having an "adjustable" expansion gear. When following full stroke it uses one cubic foot of steam per stroke, at initial pressure; when "cutting off" at half stroke, one-half cubic foot, and at a cut-off of one quarter, one-fourth of a foot, are used. The quantity used is always inversely as the ratio of expansion. To determine the best ratio of expansion: Construct a

curve, *O A*, of which the abscissas along *O X* are proportional to the amount of steam used, while the ordinates parallel to *O Y* are proportional to the absolute mean pressure for that degree of expansion, and therefore to the "total work" done by the steam so measured off. Drawing a line, *B C*, parallel to the base, and at a height proportional to the back pressure in the engine cylinder, the ordinates measured from any point in the curve down to this line will measure the

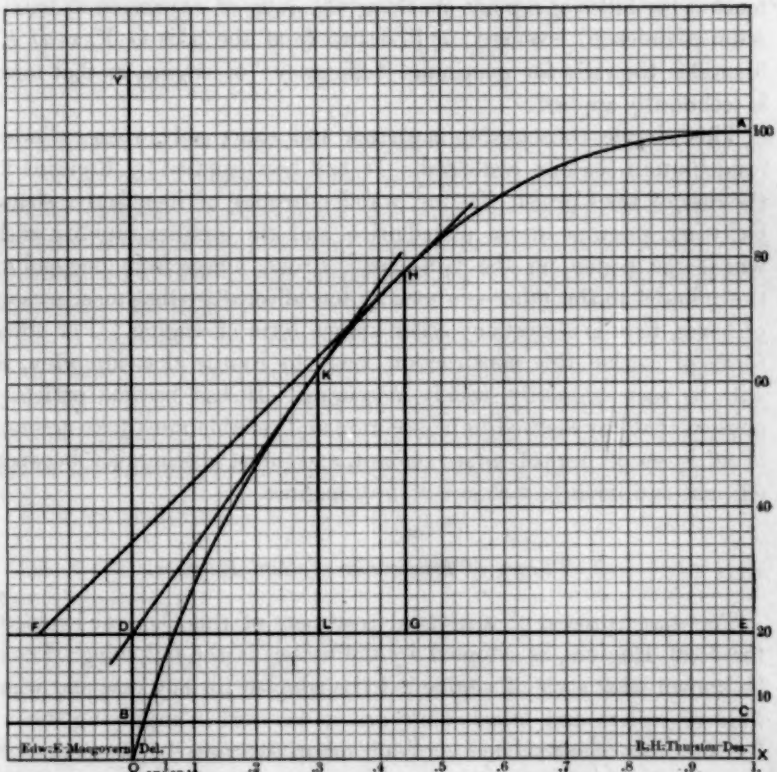


Fig. I.

"effective pressure" shown by the indicator, and will be proportional to the "indicated power" of the engine. Again: Drawing a line, *D E*, at the height measuring the sum of all useless resistances, the "net" or "dynamometric" power of the engine, as transmitted to the machinery of transmission, is measured by this line. Finally, extending this second line toward the left, and measuring off upon it a dis-

tance proportional to the cost of operation, so far as it varies with changes in plant, and measured on the same scale as is used in laying off the base line in terms of cost of steam, the sum of the two costs, *G F*, measures the total variable expense of obtaining the power, while the height of ordinate *G H*, measured from the last drawn line, is proportional to the amount of power obtained. For any one point, *F*, the straight line *F H*, drawn just tangent to the curve, touches the latter at a point marking the ratio of expansion at maximum commercial economy, or if drawn from the axis *O Y*, as *D K*, identifies the ratio for maximum "efficiency" of engine, as that term is technically applied.

This simple construction is correct and exact only when cylinder condensation may be neglected. It has been applied by Rankine to the case of the Cornish Engine, which—because of its effective steam jacketing, singular steam distribution and the peculiar rapidity with which the piston, on the "in-door" stroke, jumps from one end of the cylinder to the other—is usually less affected by that most serious of losses, than is almost any other known form of engine. For other forms of engine this construction leads to results that are often, as will be seen presently, widely inaccurate. It has become perfectly obvious that any method to be accurate and reliable must take account of *all* losses of heat of large amount, and must distinguish between efficient and inefficient classes of heat engines.

7. *Theory of Efficiencies of Real Engines.*

The direct process of analytical treatment of this General Problem for Real Engines, as adopted by the writer, is the following: Let it be known what style of engine is to be adopted for any case and what kind of boilers and attachments are to be used in supplying steam; let the costs of attendance and all other expenses be ascertainable. Then, to adopt Rankine's terms, determine *A*, the annual variable "cost of engine" of the selected type, per cubic foot of steam cylinder, and *B*, the annual variable "cost of boiler," per cubic foot of steam cylinder supplied without expansion and without allowance for cylinder condensation or leakage; ascertain all other costs, invariable with change of size of either engine or boiler within the range of the problem, and call their total *C*.

The "cost of engine" will be $A\,v_2 = A\,r\,v_1$; the "cost of boiler" will be $B\,v_1$ and the constant charges C. Make $\frac{A}{B} = M$.

The work done per stroke may be called W_n, and work per annum becomes $2RW_n$.

The ratio of the total of annual variable costs of power to work done by the engine is:

$$u = \frac{A\,r\,v_1 + B\,v_1}{2\,R\,W_n} = \frac{A\,v_2 + B\,v_2 r^{-1}}{2\,R\,W_n}$$

which is a minimum when $\frac{M+r^{-1}}{W_n}$ is a minimum.

This value of W_n may be obtained by multiplying the value of W_n for adiabatic expansion, such as would be obtained in a non-conducting cylinder by a factor variable with the ratio of expansion, as has been shown in the preceding page, which shall measure the ratio of actual work done in the metal cylinder to that done in adiabatic expansion. Or thus:

Let b represent the proportion of steam present in the working fluid when $R = 1$, as determined by the amount of cylinder condensation, let r^q represent the rate of variation of losses with increase of the ratio of expansion, and let n be the index for the actual expansion line of the mixture, to be determined, if possible, by experiment.

Then we shall have: $W_n = 2\,R\,b\,p_1\,v_2\,\frac{n\,r^{-1} - r^{-n}}{n-1}\,r^q - p_b\,v_2$.

The "General Equation of all Steam Engine Efficiencies," therefore, is

$$V = \frac{1}{E^{iii}} = \frac{A\,v_2 + B\,v_2\,r^{-1}}{2\,R\left(b\,p_1\,v_2\,\frac{n\,r^{-1} - r^{-n}}{n-1}\,r^q - p_b\,v_2\right)} \qquad (A)$$

which becomes a minimum and makes the *Commercial Efficiency* of an engine doing the required work a maximum when, to obtain r_e^{iii}, we have made

$$r^q + \frac{q}{M\,(q-1)}\,r^{q-1} - \frac{q-n}{n(q-1)}\,r^{q-n+1} - \frac{q-n+1}{Mn(q-1)}\,r^{q-n} = \frac{n-1}{Mnb(q-1)}\,\frac{p_b}{p_1} \qquad (B)$$

When the ratio of expansion, r_e^{iv}, at "*Maximum Efficiency of Fixed Plant*" is required, Av_2 is constant and we may make

$\frac{A + \frac{C}{v_2}}{B} = N$ and the equation of *Efficiency of Plant*

$$V = \frac{1}{E^{iv}} = \frac{N + r^{-1}}{2B^{-1}R_1^1\left(bp_1v_2\frac{nr^{-1} - r^{-n}}{n-1}r^q - p_bv_2\right)} \qquad (C)$$

gives, similarly, for r^{iv} and a maximum,

$$r^q + \frac{q}{N(q-1)}r^{q-1} - \frac{q-n}{n(q-1)}r^{q-n+1} - \frac{q-n+1}{Nn(q-1)}r^{q-n} = \frac{n-1}{Nnb(q-1)}\frac{p_b}{p_1} \qquad (D)$$

To obtain r_e^{ii} for *Maximum Efficiency of Engine*, we make $N = 0$ and have

$$\frac{q}{q-1}r^{q-1} - \frac{q-n+1}{n(q-1)}r^{q-n} = \frac{n-1}{nb(q-1)}\frac{p_b}{p_1} \qquad (E)$$

and to obtain *Maximum Efficiency of Fluid*, p_b becomes p_3 and

$$\frac{q}{q-1}r^{q-1} - \frac{q-n+1}{n(q-1)}r^{q-n} = \frac{n-1}{nb(q-1)}\frac{p_3}{p_1} \qquad (F)$$

in which r_e^i satisfies the equation.

When $b = 1$ and $q = 0$, we have the *ideal* case considered in § 5 and the equation (B) for r_e^{iii} becomes, as before, for the perfect engine:

$$r^{-n} - M\frac{n - nr_1^{-n}}{n-1} = \frac{p_b}{p_1} \qquad (G)$$

for Maximum Commercial Efficiency; and we again obtain for Maximum Economy of a Given Plant, for r_e^{iv},

$$r^{-n} - N\frac{n - nr^{1-n}}{n-1} = \frac{p_b}{p_1} \qquad (H)$$

For Maximum Efficiency of Engine, we again get a value of r_e^{ii}, such that

$$r^{-n} = \frac{p_b}{p_1} \qquad (I)$$

and finally for Maximum Efficiency of Fluid we find a value of r_e^i such that

$$r^{-n} = \frac{p_3}{p_1} \qquad (J)$$

precisely as already stated in § 5.

The quantities of steam and of fuel used per hour and per horse-power in the non-conducting cylinder with and without expansion, and in the metal cylinder, with and without expansion, are as

$$1 : \frac{p_1}{p_m r} \text{ and } \frac{1}{br^{-n}} : \frac{p_1}{bp_m r^{n+1}}.$$

In general, where the Equation of the Curve of Efficiency is given, we shall have at Maximum Efficiency of Fluid

$$\frac{dy}{dx} = \frac{p_m - p_3}{p_1} b r^{n+1};$$

at Maximum Efficiency of Engine,

$$\frac{dy}{dx} = \frac{p_m - p_b}{p_1} br^{n+1};$$

at Maximum Efficiency of Plant,

$$\frac{dy}{dx} = \frac{p_m - p_b}{1 + br^{n+1}N} \frac{br^{n+1}}{p_1},$$

and at Maximum Efficiency of Capital,

$$\frac{dy}{dx} = \frac{p_m - p_b}{1 + Mbr^{n+1}} \frac{br^{n+1}}{p_1};$$

for cases met with in practice; while the purely thermo-dynamic treatment gives

$$\frac{dy}{dx} = \frac{p_m - p_3}{p_1} r; \quad \frac{dy}{dx} = \frac{p_m - p_b}{p_1} r;$$

$$\frac{dy}{dx} = \frac{(p_m - p_b)r}{p_1(1 + Nr)}; \quad \frac{dy}{dx} = \frac{(p_m - p_b)r}{p_1(1 + Mr)}$$

for these several cases for the perfect engine.

For the *ideal* case, x and y being the co-ordinates, the equation of the Curve of Efficiency gives

$$\frac{y}{x} = \frac{p_m}{p_1} \div \frac{1}{r} = \frac{n - r^{1-n}}{n - 1};$$

for the real engine,

$$\frac{y}{x} = \frac{p_m}{p_1} \div \frac{1}{br^{n+1}} = b^2 r^{2n} \frac{n - r^{1-n}}{n - 1}.$$

It will be remembered that ordinates represent the work done by the quantities of steam measured by the corresponding abscissas.

The constants in these formulas should be carefully determined, if possible, by experiment on the class of engine to be designed; but, in

the absence of better data, are taken by the writer, when designing, as follows, for good practice:

	b	q	n
I Cylinders jacketed, steam superheated at boiler,	0·90	0·	1·06
II Cylinders jacketed, steam saturated, but dry at boiler, ...	0·85	—0·25	1·06
III Cylinders unjacketed, steam saturated, but dry at boiler, . . .	0·85	—0·3	0·98
IV Cylinders unjacketed, steam wet, .	0·80	—0·5	0·95

n is the exponent of the actual probable curve.

Case I is illustrated by the best work yet done by Corliss, Leavitt and Cowper. The value of b is obtained by comparing the actual results of test with the figures for the perfect engine to determine the waste; that of n is obtained by consideration of the fact that in these engines, when effectively jacketed, the steam is retained just dry and saturated during the stroke, and q is taken to be 0, since the rate of transfer of heat to exhaust is nearly constant for such engines so far as known and is of minimum amount. The second case is obtained by examining scattered records of somewhat less efficient engines. The values of b and q for III are obtained by studying the performance of good unjacketed engines; while the last, IV, came originally from the results of test of the U. S. Steamer *Michigan*, with an allowance of ten per cent. for the unrecorded waste concealed by re-evaporation.

8. *Curve of Efficiency for Real Engines.*

The correct curve for the diagram, as has been seen, is neither that due adiabatic nor that given by isothermal expansion, nor is it any known intermediate curve; it has not yet been expressed by any exact equation.* It is never the curve of mean pressures, obtained on the assumption of any yet classified method of expansion and rarely approximates to either of the ideal engine curves. It is very variable in location, in form and in dimensions and, as yet, can only be determined by experiment.

In the diagram above given, it is thus evident, the quantities of steam laid down in mathematical progression on the base line cannot

* An inspection of these curves would indicate that the equation, $y = ae^{-b^c r^d}$, may be more exact than the more manageable forms used by the writer. The general character of these curves was first pointed out by him in debate at the meeting of the Am. Soc. Mech. Engrs., May, 1881.

now correspond with the ratios of expansion there taken; since in actual engines those values are not in exact, or in constant, inverse proportion. The quantity of steam drawn from the boiler is not measured by the volume of cylinder open to steam up to the point of cut-off; nor is the mean pressure obtained with any given weight of steam drawn from the boiler at each stroke, even approximately, equal to that given by adiabatic expansion in a non-conducting cylinder. Both these causes operate to depress and flatten the Curve of Efficiency on the diagram, and thus often to reduce the ratio of economical expansion far below that predicted when the former and impossible conditions were assumed. The vertical scale of pressures and the horizontal scale of ratios of expansion have become altered in relative magnitude, and the latter becomes for usual cases a variable scale.

To obtain a solution of the actual problem as presented daily to the designing engineer, a new method of procedure must be adopted. The writer proposes the following as simple in principle, easy of application and especially as giving, from the use of experimentally derived data, results which may be received with confidence and used for any engine falling into the class of typical cases studied.

9. *Thurston's Diagram and Curve of Efficiency.*

It has become evident that the best ratio of expansion or proper "point of cut-off" for any actual case is determined, not by the percentage of loss sustained at that point simply, or by the cylinder condensation there taking place, but by the *method of variation* of such loss, not only at that point but all along the curve of efficiency and at other ratios of expansion, for, in the metallic cylinder, the proportion of the water present in the working fluid is constantly varying with change of volume and the loss of pressure and of work is constantly and proportionally varying, producing a curve of efficiency differing greatly in character, form and location from that given by a non-conducting cylinder.

This "Curve of Efficiency," as discovered by the writer and first described in the paper already referred to, is therefore a curve of peculiar character and essentially different from the line of mean pressures used by Rankine. It is obtained thus:

Assume for the unit of measure so much steam as is drawn from the boiler at one stroke of piston, without expansion, draw OX and divide it as unity of volume or of weight into a scale of equal frac-

tional parts which are to be laid down on both sides of *O*. Erect at *X* a perpendicular, *XAB*, and divide it into any convenient number, say 100, of equal parts. Were there no condensation, the fluid being worked in a vessel of non-conducting material, instead of an iron steam-cylinder, the mean pressure at full stroke and the work done per cubic foot or per pound of boiler steam would be measured by *XB*, and the curve of mean total pressures or of steam used per "total" horse-power per hour would be *OWB*.

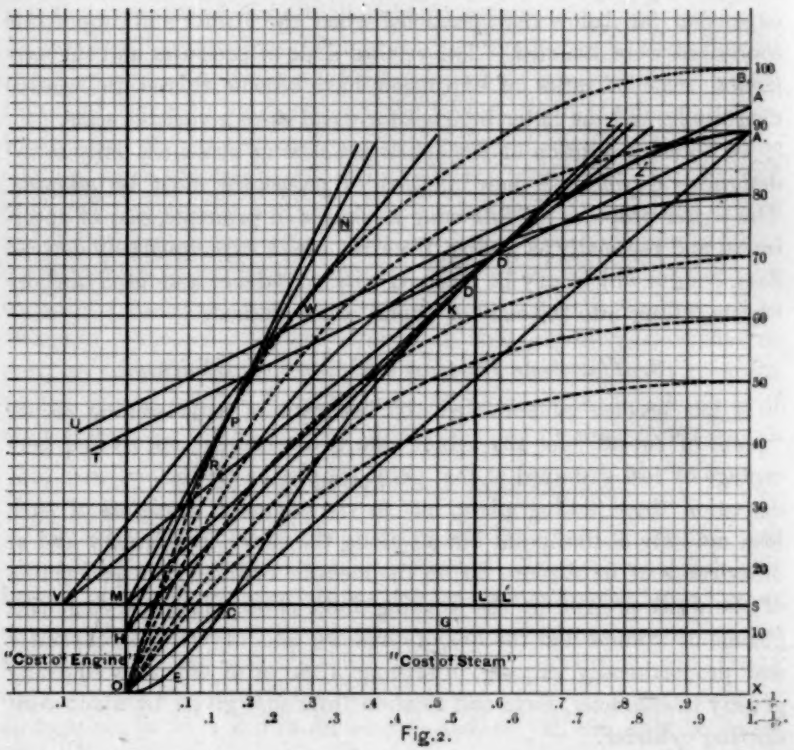


Fig. 2.

Condensation reduces the work at full stroke and it is actually measured by *XA*. Were the condensation in constant proportion for all values of the real ratio of expansion, the ordinates of the true curve would be proportional to those of *OB*, and the values of $\frac{1}{r}$ would remain proportional to the expenditure of steam as in adiabatic expansion. But the amount of condensation usually increases,

and often very rapidly, with increasing expansion and at one-half, one-quarter or one-eighth cut-off, more, and sometimes much more, than one-half, one-quarter or one-eighth as much steam is used as at full stroke. The scale of ratios, $\frac{1}{r}$ is thus not only shifted but is made a scale of unequal parts, of which the successive values must be located by determining the amount of steam used at each point of cut-off, and placing the value $\frac{1}{r}$ opposite the value of the corresponding amount of steam expended, as has been done in Fig. 2.

It may be remarked here that if, as is sometimes nearly true, the losses by condensation and leakage, or both, are so great as to annul the benefit derived from expansion, the curve flattens down to a straight line, OA. In every engine a point is reached by increasing r at which the amount of steam used per hour per total horse-power is as great as at full stroke; in every case, therefore, the true curve crosses the line OA, as at C. In every unjacketed and perhaps in jacketed engines, a point is reached before the curve terminates at O, at which the ratio of expansion becomes so large, the expenditure of steam so small and losses so great, that the curve falls nearly to the axis OX; thus instead of crossing OX, and extending through O', has a point of contrary flexure between C and O. The line O, C, E, A is thus representative of the class of mean pressure or efficiency curves given by actual engines. Could the variation of expenditure of heat be exactly expressed by an algebraic equation, this equation would be that of the line $ACEO$, and the problem would be capable of exact solution by algebraic methods.

Another, and, in some respects more readily understood, although less exact, method of constructing the curve of efficiency is to make the base scale a uniform scale *both* of steam consumption and of cut-off, as for adiabatic expansion, and then to make the ordinate, at any point, proportional to the quantity of work done at the given point of cut-off by the quantity of steam there measured, as was done in the preceding paper.

10. Solution of Problems of Efficiency for Actual Engines.

Draw HG at a height above OX equal to the back pressure, p_3; then the tangentline HK identifies a point K, which gives the ratio of expansion at *maximum efficiency of fluid*—since the ordinate GK meas-

ures the work done by the steam drawn from the boiler—and the ratio $\frac{GK}{HG}$ becomes a maximum at K. Drawing ML to represent the pressure demanded to overcome all useless resistance, $p_v = p_s + p_r$, a similar construction identifies D as the point corresponding to the ratio of expansion at *maximum efficiency of engine*. Finally, extending this line to V and making VM proportional to cost of all variable running expenses, stated in terms of cost of steam per cubic foot of cylinder, $VM = \frac{A}{B} = M$, when working at full stroke, the tangent line VZ meets the curve at a point near D' which gives the ratio of expansion at *maximum commercial efficiency*. Comparing these values of r with those given by the tangents, HR, MP, VW, drawn to the curve OB, for dry saturated steam, expanded adiabatically, it is seen that the best ratio of expansion must be, in each actual example, less than in the hypothetical case and may even become unity for each kind of *efficiency*, with very slow piston speeds, where, were no loss of heat to occur in the manner here considered, considerable expansion would be desirable. These differences all become greater as the back pressures and current expenditures become less.

Making the value of VM a measure of the total current expenses including the constant as well as variable items of cost, of attendance, as those of rent, insurance, etc., which do not depend on size of engine, $VM = \frac{A'}{B} = N$, a value of r will be obtained which is that real ratio of expansion at which *maximum work is done for a given expenditure*, per hour or per annum, on a plant actually established. This problem is less frequently presented to the engineer than those already given, and is not the problem of maximum commercial efficiency; since this ratio and the corresponding power of engine being determined, it will be found on solving for maximum commercial efficiency that another proportion of engine with higher ratio of expansion will supply the power now demanded at still lower cost. To this latter engine the last problem again applies. The practical conclusion to be drawn from the solution of the interminable succession of problems of this last character, which thus follow the first, is that the largest amount of power possible should be entrusted to a single engineer, or crew of attendants, and placed under one roof, etc. In this last case, all

To secure natural perspective through the semi-lenses press the brass and wooden screens flat (Fig. 1), and use the instrument as an ordinary stereoscope. Assuming the stereographic interval to be average, and the distance between the observer's eyes to be not greater than usual, comfortable vision will be secured by turning the adjusting screws until the semi-lenses are pressed as near as possible together. The light which enters the pupils then passes through the thicker part of each semi-lens, and the optic angle is positive and small, or

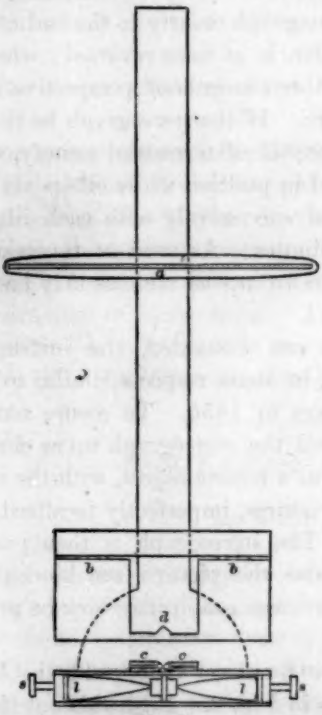


Fig. 1.

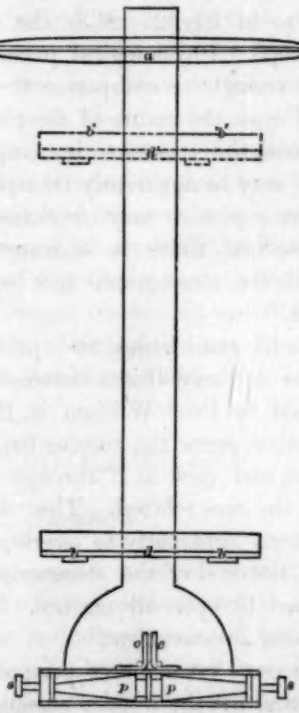


Fig. 2.

the visual lines may be sensibly parallel. If the observer's interocular distance is much greater than usual, the rays of light which he receives will be transmitted still nearer the base of the semi-lens, and slight optic divergence is necessary. This is avoided by giving a few leftward turns to the screw, permitting the semi-lenses to be pressed a little farther apart by the opposing springs. The same can be done to secure comfortable vision when the stereographic interval is great;

pictures 10 cm. apart can thus be viewed without discomfort, and without any very objectionable degree of coloration in consequence of want of achromatism in the semi-lenses. By now turning the screws so as to press the glasses closer together, any degree of optic divergence may be attained that the observer is willing to endure, while the picture is still seen in natural perspective, distances being apparently slightly magnified, and diameters also in the same ratio.

To secure reversed perspective, lift up the wooden screen, fold the brass hinges outward in front, and substitute the prisms for the semi-lenses, as in Fig. 2. Slide the stereograph nearly to the end of the stereoscope. Physiological perspective is at once reversed; whether this is enough to overpower the other elements of perspective must depend upon the nature of the picture. If the stereograph be that of the moon, the reversion is complete; if of terrestrial scenery, some objects may be apparently transposed in position while others are not. The same picture may be examined successively with each illusive effect several times in as many minutes. As soon as reversion is attained the stereograph may be drawn up as close as may be convenient.

If both semi-lenses and prisms are discarded, the instrument becomes a direct-vision stereoscope, in some respects similar to that described by Prof. William B. Rogers in 1855. To secure natural perspective press the screens flat, pull the stereograph up as close as possible, and gaze as if through it at a remote object, with the muscles of the eyes relaxed. The two pictures, imperfectly focalized, are dimly seen apparently to overlap. The stereograph is then pushed out to the end of the stereoscope, and the pictures are binocularly combined by optic divergence. The stereograph may now be pulled up as near as convenient.

To secure reversion of perspective by direct vision fold the brass hinges and lift the wooden screen, as in Fig. 2. Push this out (b' b') as near as possible to the stereograph at the end of the instrument, then pull it up, keeping the gaze fixed upon the projection (d') at the top. This grows dim as it approaches its previous position. Without changing the direction of the visual lines, except slightly to lower them, transfer the attention to the stereograph beyond. The combined picture is seen in reverse perspective, apparently much smaller and nearer than when the prisms were employed.

Those who have tried this instrument thus far have usually suc-

ceeded at the first attempt, for either natural or reverse perspective, when the glasses were used. Several trials are often necessary before success is attained by direct vision, but the variation in perspective thus attained is much more striking. But little experiment is needed to prove to any one who is thus successful that in the localization of objects in the binocular field of view presented by the stereograph, the current theory of successive triangulation by intersection of visual lines is inapplicable. The only substitute that covers the facts which the geometric theory fails to account for is that of associated muscular action, which applies to divergence as well as convergence of visual lines.

The use of adjusting screws for the semi-lenses of the stereoscope is, of course, not a novelty. They were thus applied by Duboscq, about 1850, to one of Brewster's stereoscopes, and also, subsequently, by Helmholtz. A similar application is especially described by Prof. Emerson in this journal, Nov., 1861, and Emerson's stereoscope was for a number of years made by Messrs. Anthony & Co., of New York. It would indeed be difficult to evolve any wholly new principle in the construction of stereoscopes. The present instrument was devised for a specific purpose, which it accomplishes successfully.

40 West Fortieth street, New York, Jan. 21st, 1882.

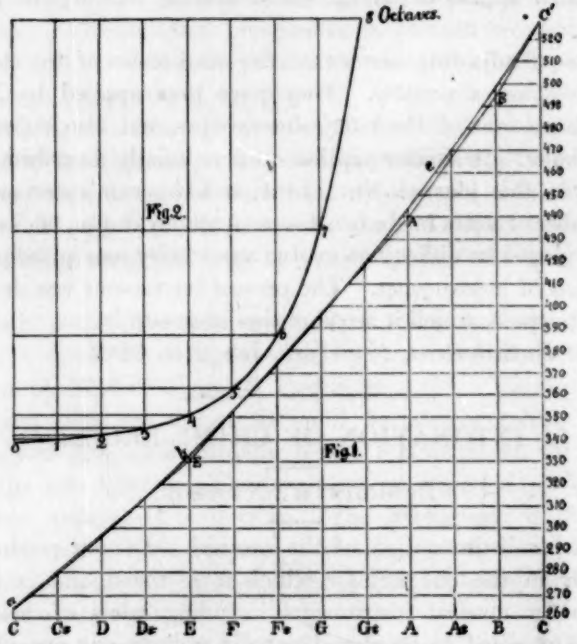
INTONATION OF CHIME-BELLS.

By JOHN W. NYSTROM.

The harmonic intonation of the musical scale can produce good music only in the one key for which it is toned, and is therefore unsuitable for musical instruments including peals of bells, upon which it is expected to be played equally well in any one of all the different keys. The harmonic intonation divides the musical scale into an irregular order, found to be most agreeable to the ear and can be used only in vocal music, but for musical instruments it has been found necessary to divide the scale into a regular order called the tempered scale. In his extensive and excellent work on "The Sensations of Tone" Helmholtz gives various methods of tempered intonation, each named after its respective author; but none of these methods, as far as the writer has been able to find, has given a perfectly tempered intonation.

The writer's attention has been called to this subject in the construction of peals of bells which are required to ring music in different keys. A peal of eight bells, or an octave of the diatonic scale with harmonic intonation, can ring harmonic music only in the key for which it is toned and will be wrong for any other key, even if one or more bells are added to the peal. A peal of any number of bells, with tempered intonation, can ring equally correct in any one of all the keys.

The pitch of tone produced by any vibrating body is proportionate



to the number of vibrations per unit of time usually expressed *per second*. The octave above any tone makes double the vibrations of its octave below, and each note in the musical scale has a definite number of vibrations depending upon its position.

For the tempered intonation of the musical scale, the number of vibrations of each note is a term in a geometrical progression, that is, the vibrations of any one note, multiplied by a certain ratio, give the vibrations of the next note above. The octave is divided into twelve equal parts, making thirteen terms, including sharps or flats. We

have now all the data necessary for the tempered intonation by the formulas of geometrical progression.

C = first term, or vibrations of the fundamental note.

c = the last term, or vibrations of the octave above the fundamental note. $2\,C = c$.

n = number of vibrations of any note in the musical scale whose number of terms, from C inclusive, is a.

a = number of terms between C and n inclusive.

r = ratio of vibrations between each note or term.

Each term multiplied by the ratio r gives the next following term, when the progression is increasing.

$$\text{Ratio } r = \sqrt[a-1]{\frac{c}{C}} \cdot \quad \text{Vibrations } n = C\,r^{a-1}.$$

In the application of these formulas to the division of the octave into the chromatic scale of thirteen notes, we can assume any arbitrary number of vibrations of the fundamental note, say $C = 32$, and the octave will then vibrate $c = 64$, making $a = 13$, we find the

$$\text{Ratio } r = \sqrt[a-1]{\frac{c}{C}} = \sqrt[13-1]{\frac{64}{32}} = \sqrt[12]{2.}$$

$$\text{Log. } r = \frac{\log. 2}{12} = \frac{0{\cdot}30102999566}{12}$$

$$= 0{\cdot}02508583 = \log. 1{\cdot}059462 \text{ the ratio.}$$

The proportionate vibration of any note, whose number from C inclusive is a, will be

$$n = C\,r^{a-1} = 32 \times 1{\cdot}059462.^{a-1}$$

The number a includes also the half-notes or sharps.

Example.—The note G is the eighth term above C, making $a = 8$; how many vibrations will G make?

Vibrations $n = 32 \times 1{\cdot}059462^{8-1} = 47{\cdot}9458$, the answer.

The calculation is easily accomplished by logarithms, as follows:

log. 1·059462	= 0·02508583
multiply	7
	0·17560081
log. 32	= 1·50515000
log. 47·9458	= 1·68075081

The harmonic intonation of the diatonic scale is established as follows:

TABLE I.

	C	D	E	F	G	A	B	c
	1	$\frac{9}{8}$	$\frac{5}{4}$	$\frac{4}{3}$	$\frac{3}{2}$	$\frac{5}{3}$	$\frac{15}{8}$	2
Harmonic,	32	36	40	$42\frac{2}{3}$	48	$53\frac{1}{3}$	60	64
Tempered,	32	35·9188	40·3175	42·7149	47·9458	53·8174	60·408	64
Difference,	0·000	−0·0812	+0·3175	+0.0483	−0·0542	+0·4841	+0·408	0·000

The actual number of double vibrations, per second, of the standard concert pitch now generally used was established by a Congress of Philosophers, which met in Stuttgart in the year 1834, namely, $C' = 264$, $A' = 440$ and $C'' = 528$. With this data the following table is calculated.

The Italic numbers of vibrations in the harmonic column n' are inserted by the writer, being the mean difference between the whole notes. The harmonic scale, as established at Stuttgart, advances in an arithmetical progression with constant differences in different portions of the octave. The difference in vibrations, between each half note, is 16·5 from *C* to *E*, 22 from *E* to *A*, 27·5 from *A* to *B* and 33 from *B* to *C*. Thus, the terms of vibrations do not form a regular curve, but a broken straight line making corners at *E*, *A* and *B*, as shown in the accompanying illustration, Fig. 1. It is, indeed, singular that such an irregular progression can bear the title of *harmonic*.

The tempered intonation, column *n*, ascends in a geometrical progression forming a regular curve *a*, *b*, *c*, *C''*, Fig. 1. The difference in vibrations between each half note increases in a regular order, and the vibration of each note bears a certain ratio to that of the next one above or below. The two centre columns in the table show the difference between the two systems of intonation.

The last column, "Prop. length of waves," shows the proportionate diameters of bells for the corresponding note, when the sound-bow is of a certain proportion to the diameter in all the bells. This column also shows how to divide the bridge on a *guitar*, when the whole length of the string being 1 or the unit.

The tables III to VI contain the vibrations of each note in the chromatic scale, commencing with C = 33 vibrations and extend through eight octaves to C = 8448 vibrations per second, with the corresponding logarithms. Tables of this kind are necessary for the proper proportions and construction of peals of bells.

Table II.

Harmonic and Tempered Intonations.

Stuttgart Harmonic Scale.				Difference.		Tempered Geometric Scale	
Terms a	Keynote.		Double Vibrations n'	Ratio of Pitch $\frac{n}{n'}$	In Vibration. $n-n'$	Double Vibrations n	Prop. Length of waves. $\frac{264}{n}$
13	C		528	1·00000	0·000	528	0·50000
			33			29·635	
12	B		495	1·00680	+3·365	498·365	0·52973
			27·5			27·970	
11	A♯		*467·5*	1·00616	+2·895	470·395	0·56123
			27·5			26·402	
10	A		440	1·00908	+3·993	443·993	0·59461
			22			24·919	
9	G♯		*418*	1·00257	+1·074	419·074	0·62996
			22			23·519	
8	G		396	0·99887	—0·447	395.553	0·66742
			22			22·201	
7	F♯		374	0·99827	—0·648	373·352	0·70711
			22			20·954	
6	F		352	1·00113	+0·398	352·398	0·74915
			22			19·787	
5	E		330	1·00794	+2·611	332·611	0·79370
			16·5			18·660	
4	D♯		*313·5*	1·00144	+0·451	313·951	0·84090
			16·5			17·621	
3	D		297	0·99774	—0·670	296·330	0·89090
			16·5			16·638	
2	C♯		*280·5*	0·99714	—0·808	279.692	0·94388
			16·5			15·692	
1	C		264	1·00000	0·000	264	1·00000
			16·5			14·817	

Table III.

Tempered Intonation of Musical Vibrations.

Keynote.		Vibrations. n.	Log. n.	3 Log. n.
2	C	132·	2·1205739	6·3617217
	B	124·591	2·0954867	6·2864601
	A♯	117·598	2·0704000	6·2112000
	A	110·998	2·0453153	6·1359459
	G♯	104·768	2·0202286	6·0606858
	G	98·888	1·9951436	5·9854308
	F♯	93·338	1·9700586	5·9101755
	F	88·099	1 9449710	5·8349130
	E	83·152	1·9198727	5·7586181
	D♯	78·488	1·8948033	5·6844099
	D	74·082	1·8697127	5·6091381
	C♯	69·923	1·8446201	5·5338603
1	C	66·	1·8195439	5·4586317
	B	62·295	1·7944532	5·3833696
	A♯	58·799	1·7693699	5·3081097
	A	55·499	1·7442852	5·2328556
	G♯	52·384	1·7191987	5·1575861
	G	49·444	1·6941136	5·0823408
	F♯	46·669	1·6690285	5·0070855
	F	44·049	1·6439361	4·9318083
	E	41·576	1·6187487	4·8562461
	D♯	39·244	1·5937733	4·7813199
	D	37·041	1·5686827	4·7060481
	C♯	34·961	1·5435838	4·6307514
0	C	33·	1·5185139	4·5555417

Table IV.

Tempered Intonation of Musical Vibrations.

Keynote.		Vibrations. n.	Log. n.	3 Log. n.
4	C	528·	2·7226339	8·1679017
	B	498·365	2·6975480	8·0926440
	A♯	470·395	2·6724722	8·0173866
	A	443·993	2·6473764	7·9421292
	G♯	419·097	2·6222905	7·8668715
	G	395·552	2·5972047	7·7916141
	F♯	373·352	2·5721189	7·7163567
	F	352·398	2·5470330	7·6410990
	E	332·611	2·5219472	7·5658416
	D♯	313·951	2·4968614	7·4905832
	D	296·330	2·4717755	7·4153265
	C♯	279·602	2·4477897	7·3400691
3	C	264·	2·4216039	7·2648117
	B	249·182	2·3965167	7·1895501
	A♯	235·197	2·3714319	7·1142957
	A	221·997	2·3463471	7·0390413
	G♯	209·537	2·3212400	6·9637200
	G	197·776	2·2961736	6·8885208
	F♯	186·676	2·2710885	6·8132655
	F	176·199	2·2460035	6·7380105
	E	166·305	2·2209053	6·6627159
	D♯	156·975	2·1958305	6·5874915
	D	148·165	2·1707457	6·5122371
	C♯	139·846	2·1456501	6·4369503
2	C	132·	2·1205739	6·3617217

Table V.

Tempered Intonation of Musical Vibrations.

Keynote.	Vibrations. n.	Log. n.	3 Log. n.
C	2112·	3·3246939	9·9740817
B	1993·46	3·2996076	9·8988228
A♯	1881·58	3·2745227	9·8235681
A	1775·97	3·2494356	9·7483068
G♯	1676·30	3·2243517	9·6730551
G	1582·21	3·1992641	9·5977923
F♯	1493·41	3·1741790	9·5225370
F	1409·59	3·1490928	9·4472784
E	1330·44	3·1239953	9·3719859
D♯	1255·80	3·0989205	9·2967615
D	1185·32	3·0738356	9·2215068
C♯	1118·77	3·0487408	9·1462224
C	1056·	3·0236639	9·0709917
B	996·730	2·9985775	8·9957325
A♯	940·780	2·9734881	8·9204643
A	887·986	2·9484061	8·8452183
G♯	838·148	2·9231707	8·7695121
G	791·106	2·8982347	8·6947041
F♯	746·704	2·8731485	8·6194455
F	704·796	2·8480634	8·5441902
E	665·222	2·8229666	8 4688998
D♯	627·902	2·7978919	8·3936757
D	592·660	2·7728056	8·3184168
C♯	559·384	2·7477100	8·2431390
C	528·	2·7226339	8·1679017

Table VI.

Tempered Intonation of Musical Vibrations.

Keynote. 3 Octaves above.		Vibrations. n.	Log. n.	3 Log. n.
8	C	8448·	3·9267539	11·7802617
	B	7973·84	3·9016675	11·7050025
	A♯	7526·32	3·8765827	11·6297481
	A	7103·88	3·8514957	11·5544871
	G♯	6705·20	3·8264119	11·4792351
	G	6328·84	3·8013241	11·4039723
	F♯	5973·64	3·7762390	11·3287170
	F	5638 36	3·7511528	11·2534584
	E	5321·76	3·7260553	11·1781659
	D♯	5023·20	3·7009805	11·1029415
	D	4741·28	3·6758957	11·0276971
	C♯	4475·08	3·6508008	10·9524024
7	C	4224·	3·6257239	10·8771717
	B	3986·92	3·6006375	10·8019125
	A♯	3763·12	3·5755481	10·7266443
	A	3551·94	3·5504656	10·6513068
	G♯	3352·59	3·5253804	10·5761412
	G	3164·42	3·5002941	10·5008823
	F♯	2986·82	3·4752090	10·4256270
	F	2819·18	3·4501228	10·3503684
	E	2660·89	3·4250253	10·2750759
	D♯	2511·61	3·3999522	10·1998566
	D	2370·64	3·3748656	10·1245968
	C♯	2237·54	3·3497708	10·0493124
6	C	2112·	3·3246939	9·9740817

The weight of bells is proportionate inversely to the cube of the vibrations per second; also the weight of the whole peal of any number of bells is inversely proportionate to the cube of the vibrations of the tenor. The fourth columns contain the logarithms of the cubes of the vibrations, which subtracted from the logarithm of a certain coefficient, depending upon the adopted *timbre* of the bell or peal, gives the logarithm for the required weight.

Figure 2 of the illustrations represents the curve of vibrations extending through eight octaves within the limit of the tables III to VI.

The science of acoustics has now brought the art of bellfounding under perfect control, so that bells can now be cast not only with correct pitch of tone but also with any desired quality of *timbre*, which is of considerable importance. A peal of bells may be good in pitch of tone, but a discordant *timbre* may make the ringing detestable to sensitive musical ears, which is often the case.

The difference of *timbre* is caused by different *upper partials*, and when these partials consist of consonant tones the sound is agreeable to the ear, but when of discordant tones or noise, as is often the case, particularly in bells, the sound is very disagreeable to sensitive musical ears and sometimes causes melancholiness. The *upper partials* are by-tones to the ground note, and are caused by the inertia of the vibrating body. The subject of *upper partials* is very extensive and intricate, and would require a special article for elucidation.

The tables III to VI will also answer for tempered intonation of all kinds of musical instruments.

(To be continued.)

Extinction of Fire by Steam.—The *Genie Civil* proposes, for the rapid extinction of fires in theatres, to have always in readiness high-pressure boilers in operation during the representations. These boilers should communicate with steam pipes opening at places which are most exposed to danger. By an ingenious contrivance, the heat, which would be produced by a fire breaking out, could be made to give vent to the steam, which would thus automatically arrest the ravages of the flames before they had time to gain much headway. The principle of extinguishing flames by steam was proposed by Abbé Moigno about thirty years ago.—*Les Mondes.* C.

THE MEARS CHLORINATION PROCESS.

By WILKINS U. GREENE, Ph.B.

[A paper read at the Stated Meeting of the Franklin Institute, March 15, 1882.]

Gold was first discovered about the twenty-seventh or the twenty-eighth century before the Christian era. It occurs in three classes of deposits: 1st. Placer, formed by the action of water and frost on mountain sides, containing auriferous quartz veins. 2d. Segregated veins in metamorphic rocks. 3d. Fissure veins, where it is mingled with ores of iron, lead, silver, etc.

The extraction of gold from its ores is commonly effected in three ways, viz.: Smelting, amalgamation and chlorination, depending primarily upon the character and value of the ore.

The latter method, which has been hitherto chiefly known as the Plattner process, consists briefly in the treatment of properly roasted ore with chlorine gas.

The apparatus consists of a rectangular or cylindrical box, with a cover, which can be luted down; the roasted ore is placed on a false bottom and the chlorine allowed to percolate through the mass from the bottom; when the chlorine has reached the top, the cover is luted down and left for from fifteen to forty hours, in order to allow the gold in the ore to be converted into the chloride which is soluble in water; the gas left in the apparatus, after treatment, is practically thrown away, increasing the cost of working.

Upon treating the ore with water and filtering a solution is obtained which may contain 90 per cent. of the gold in the ore; an addition of ferrous sulphate now reduces the gold, which appears as a dark powder; this is collected and melted into a button of very fine bullion.

The Mears Process of chlorination is based upon the use of the gas under pressure.

The advantages attendant upon this modification, demonstrated on a working scale, are quicker work, larger percentage of extraction, no practical waste of gas and consequently less cost.

The apparatus used in this process is as follows: Chlorine gas is evolved in the generator *A* from a mixture of common salt, binoxide of manganese and sulphuric acid, in proportions of about one part of

manganese, two parts of salt and three parts of sulphuric acid; or the gas may be produced by chlorinated lime (commonly known as bleaching powder) and sulphuric acid, the choice depending on the price and facility of transportation.

The reactions are:

$$MnO_2 + 2NaCl + 3H_2SO_4 = MnSO_4 + NaHSO_4 + 2H_2O + Cl_2.$$

$$*(CaClO)_2CaCl_2 + 2H_2SO_4 = 2CaSO_4 + 2H_2O + Cl_4.$$

The salt and manganese binoxide are mixed together and introduced into the generator through an opening provided with a cover and clamp; a small quantity of water and the acid are added through the funnel, and the materials mixed by means of a stirrer. The gas passes from the generator through a wash-bottle containing pure water, which absorbs any hydrochloric acid which may be formed; it then enters the gasometer.

A pump *H* with its connections forces the gas into a receiver *F*, which stores an amount of gas under pressure of say, 50 pounds, as indicated by the attached gauge.

The chlorinator *E*, which receives the charge of ore, is an iron barrel revolving horizontally upon trunions. A one ton chlorinator is 42 inches in diameter and 54 inches in length, and makes 8 to 10 revolutions per minute. Like all the apparatus exposed to the gas, it is lined with lead; this lining has attached a series of ridges which assist the mixing of the charge; it also has a pocket of lead which is used when chlorine is produced by means of chlorinated lime.

The convex surface of the chlorinator has a charging hole, central between the trunions, and opposite is a man-hole. Through one of the trunions passes the goose-neck or pipe for the entrance of chlorine—it passes through a glass stuffing box, packed with asbestos, and held in position with a brass gland; inside it makes a vertical turn, and near the top a short turn in the direction of revolution; a branch pipe carries pressure and vacuum gauges and may be connected with a water column exhaust or pump.

Filtering vessels of iron, lined with lead, provided with perforated false bottoms of slate or tiles, upon which is placed quartz sand of different degrees of fineness, the upper layer being of finest sand; these receive the mass from the chlorinators.

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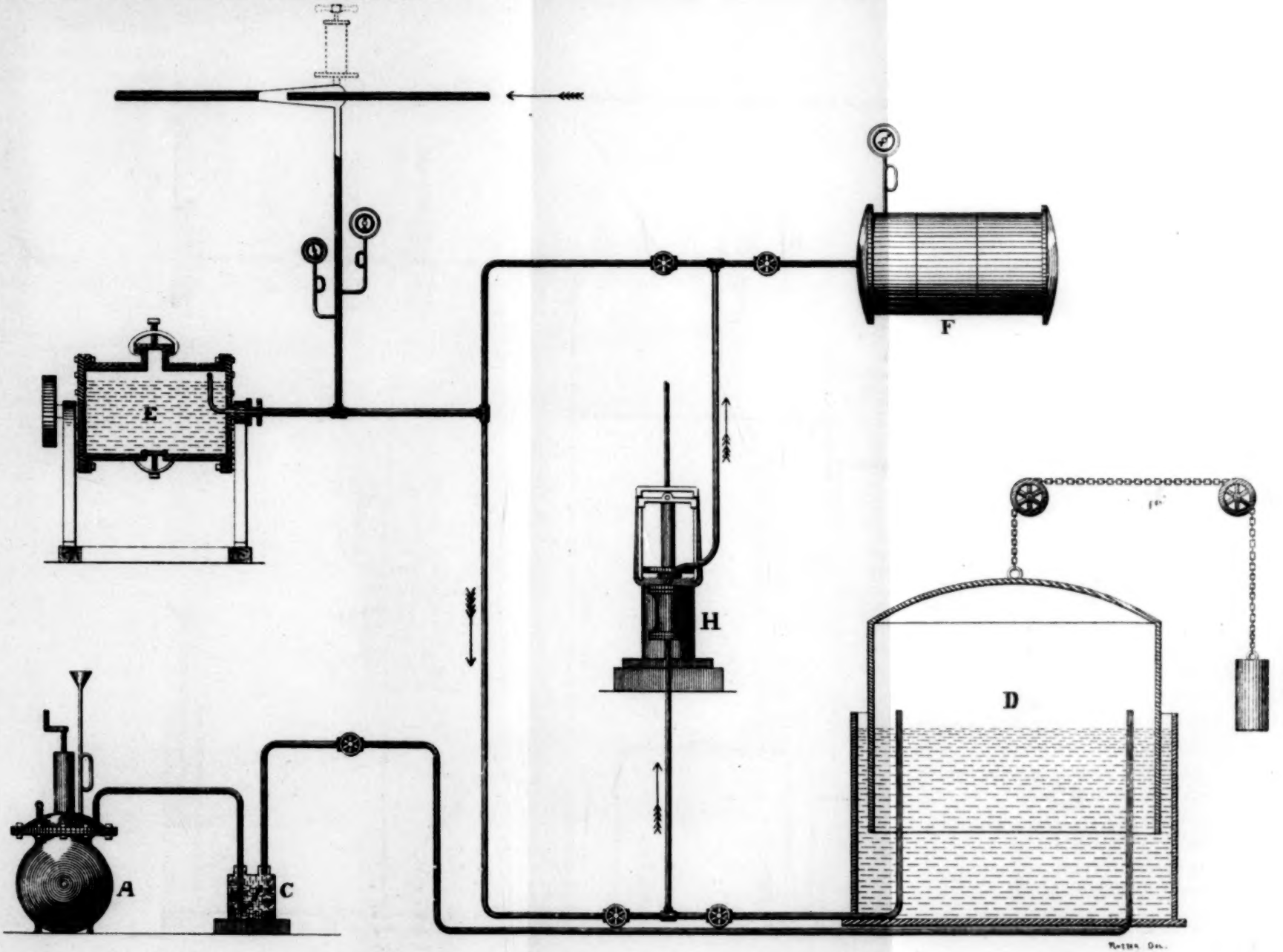
* It is not certain that this reaction is so simple. The resulting product probably contains hypochlorous acid.


F
E
H
D
A
C

The filtered liquid then passes to the precipitating tank, and after treatment with the precipitant passes into the settlers. The operation is as follows:

The sulphurets, concentrated or not, are first roasted carefully to a dead or sweet roast.

The choice of a furnace is an open matter. It is found that the continuous feeding and discharging furnace is not so to give a roast as required for chlorination—the form generally used is the reverberatory, with one or more hearths. After roasting, the ore is cooled, the requisite charge is introduced into the chlorinator through a hopper, with a quantity of water; after clamping down the cover of the chlorinator a vacuum is produced, with the water column or pump, in order that the gas may not be diluted with air. The chlorinator is then made to revolve; the proper valves are opened, all the others being closed, and the chlorine enters until the required pressure is reached. The charge being thoroughly mixed, by means of the ridges, rapidly absorbs the gas by the formation of chlorides of gold, and of the other metals which may exist in the roasted ore and may necessitate a second communication with the receiver.

At the end of from one to three hours the excess of gas is allowed to flow back into the gasholder, through other values shown in plate.

The chlorinator is now discharged into a trough connecting with one of the filters, over which the mass spreads to a depth of 3 to 4 inches. A quantity of wash-water is now let into the filter from a hose, and meanwhile the chlorinator receives a new charge. The filtrate and washings go to the precipitating tank where, after blowing a jet of steam or air through the liquid, in order to eliminate as much as possible of the chlorine gas contained in it, the presence of which would necessitate a larger use of the precipitant, a small quantity of a freshly prepared solution of ferrous sulphate (made by treating scrap iron with sulphuric acid) precipitates the gold as a dark-brown powder of extreme fineness. Large wooden settlers receive the contents of the tank for 12 hours alternately.

The settlers may be cleaned at long intervals, and the cement gold is then dried, smelted and cast into ingots.

The process, by careful working, extracts from 96 to 99 per cent. of the gold contained in the ore, varying in time and pressure with the coarse or fine nature of the gold and the amount of other soluble substances the ore may contain. The time consumed in the operations

varies from 15 minutes to 3½ hours and the pressure from 20 to 40 pounds.

The usual precipitant employed to throw down the gold in metallic conditions, as already mentioned, is the ferrous sulphate. Numerous other reagents or substances may be used, as subchloride of arsenic, sulphurous acid, sulphuretted—hydrogen, phosphorus; also, coal, sawdust, etc.

A patent has been issued to W. M. Davis, of Philadelphia, for the method of precipitating gold from its solution by allowing the same to pass through barrels of charcoal. The gold deposited on the carbon is subsequently obtained by calcination.

Mr. Davis had, previous to the issue of his patent, purchased the right to use the Mears Chlorination Process in North Carolina.

This chlorination process is especially adapted to gold ores, but ore containing gold and silver may be wrought and the silver extracted. This is accomplished by making a chloridizing roast, by the addition of a quantity of common salt at the end of the roast which converts the silver into the chloride, the process is then carried on as if no silver were present until the gold has been leached out of the ore; then a solution of hyposulphite of lime is introduced into the filter which dissolves out the silver, which is afterwards precipitated by sulphide of lime.

The question is asked whether the workmen are not affected unpleasantly by the gas? They are, if they breathe too much of it, but an apparatus can be so constructed that the air in the working-room can be kept comparatively free from the gas.

A long box is constructed, which is suspended near the ceiling, terminating on the outside of the building. At the end of this box is a powerful jet of steam or air, which causes a vacuum in the box and produces a constant draught upwards in the room.

The cost of the process depends on the price of labor, fuel, etc., the cost of treating a ton of ore varying from $1 to $3, exclusive of the roasting.

Works of fifty tons per day capacity, including best machinery, with steam-power for crushing, pulverizing, roasting, chlorinating and reducing to bullion, cost from $20,000 to $30,000.

Chlorination works, capable of handling ten tons per day of concentrated or selected sulphurets, can be attached to a stamp mill where power and pulverizing machinery are already in use, for an extra out-

lay of from $3000 to $5000, which will provide two chlorinators and all necessary filters, precipitating tanks, a retort and gas-holder, etc.

	Roasting. Time.	Chlorination. Time.	Pres.	Results per net ton. Extracted.	Tailings.	Fire assay.	Dif.+or—
1.	6 hrs.	2 hrs.	35 lbs.	$58.55	$1.24	$62.01	+$2.22
2.		1¾ hrs.	25 lbs.	20.00	.41	21.43	+ 1.02
3.	10 hrs.	3 hrs.	25 lbs.	15.58	1.13	16.21	— .50
4.	4 hrs.	1 hr.	25 lbs.	18.98	.34	18.60	— .72
5.	8 hrs.	3 hrs.	40 lbs.	48.77	.83	50.32	— .72
6.	10 hrs.	3 hrs.	25 lbs.	41.11	.41	42.37	— .85

ANALYSES.

	1	2	3	4	5	6
Silica,	10·26	72·50	11·11	72·67	29·73	18·38
				Pyrite.		
Sulphur,	41·81	15·10	47·67	1·99	25·23	35·10
Iron,	37·23	12·25	40·06	5·09	21·48	37·00
Copper,		·05	·59		2·03	
Lime,					4·06	1·60
Total,	89·30*	99·90	99·43	79·75*	62·70*	92·08*

1. Bunker Hill, Cal.
2. Boulder Co., Col.
3. Bob-tail, Col.
4. Nova Scotia.
5. Colorado Ore.
6. Plumas-National, Cal.

Injurious Elements of Illuminating Gas.—M. Pobek, of Breslau, finds that the chief poisonous agent in illuminating gas is carbonic oxide. In some cases, when the gas traverses a stratum of ground which is not yet saturated, it deposits the hydrocarburets which give it its characteristic odor and then diffuses itself in dwellings without its presence being perceived. In such cases the danger of explosion is added to that of poisoning. Explosions are comparatively rare, because the definite proportions which are required for an explosive mixture are not present. When the gas is imperfectly burnt, as in heating apparatus, there is an excess of moisture which is injurious to health.—*Chron. Industr.* C.

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* Incomplete analysis.

ACTION OF CHARCOAL UPON A SOLUTION OF GOLD CHLORIDE.

By Prof. GEORGE A. KOENIG.

Among the substances which decompose gold solutions, the text-books—and, as far as I could find, the special literature—do not mention charcoal. This property of charcoal has become the subject of a United States patent, claiming that by filtering liquids containing in solution gold and certain metallic salts, the gold alone would be precipitated upon the charcoal, and none of the other metals. In the spring of 1880 my attention was drawn to this subject, and, as the fact appeared unquestionable, it became of some interest to ascertain the reactions involved.

The following possibilities suggested themselves:

1. Gold might be precipitated by the alkaline carbonates of the ash mixed with the charcoal from the charring process.

2. Gases condensed in the coal might act as reducing agents.

3. The action might be physical only, belonging to the so-called catalytic phenomena.

4. Carbon might be oxidized by auric chloride and water, either to carbon monoxide or dioxide.

Gold hexachloride was prepared as nearly free from uncombined chlorine as several evaporations to dryness could make it.

Charcoal was broken into pieces, and, by sifting, assorted to an average diameter of about $\frac{3}{32}$ of an inch. It was then digested with hydrochloric and hydrofluoric acids for 12 hours, and washed first with dilute acid, then with distilled water until the latter ceased to act upon blue litmus. After drying, the charcoal was kept at a full red heat for one hour in a closed crucible. Any action produced by this purified material upon gold solution could not be ascribed to inorganic constituents.

First Experiment.—30 grammes of the charcoal were placed into a half-litre flask, and the latter filled one-half with water. Heat being now applied, the contents of the flask were kept boiling for 30 minutes, under replacement of the evaporating water. Condensed or occluded gases were now presumably expelled, and a measured aqueous solution of gold chloride, corresponding to 1·452 grammes of metallic gold, was added, whilst the flask was furnished with a doubly perfo-

rated cork, and left at ordinary temperature for 2 hours, when the yellow color of the liquid had disappeared and the charcoal become coated with gold. Having now connected the flask on one side with a Geissler potash bulb, filled with aqueous barium hydrate, and on the other with a gasometer, containing pure air, the flask was again brought to boiling, while a slow current of air passed into the flask, the air passing through several U tubes containing sodium hydrate. A turbidity in the barium hydrate became visible at once, and after 15 minutes of boiling the precipitate of barium carbonate was determined as barium sulphate with the usual precautions.

$$BaSO_4 = 0{\cdot}070 \text{ gr.} = 0{\cdot}0036 \text{ C.}$$

Now, according to the equation

$$(AuCl_6 + 3H_2O)_2 + C_3 = Au_2 + (HCl)_{12} + (CO_2)_3$$

we have

$$784 \text{ Au} : 36 \text{ C} = 1{\cdot}452 \text{ gr. Au} : 0{\cdot}0666 \text{ C};$$

that is to say, that only about $\frac{1}{20}$ of the gold was precipitated by the chemical action of charcoal.

A closer examination of the charcoal showed a marked difference. Some pieces had a brilliant compact coating of gold, others a dull porous coating, and many none at all.

Second Experiment.—Lampblack was strongly heated in a closed crucible to redness. It was then washed with hot water and again dried. If the action of the charcoal were chemical, then lampblack should act more readily. In order to test this assumption 0·2 gramme of gold, as chloride, was dissolved in 100 cc. of water and 6 mgr. of the above lampblack added. A disengagement of gas was noticed at the boiling heat, and also a slight precipitation of gold. Boiling was kept up for 2 hours, when the liquid was still colored from gold chloride. Again 6 mgr. of lampblack was added and boiled for 3 hours longer with a condenser attached. The liquid was now filtered and still yellow in color, while the precipitated gold was largely mixed with lampblack. After ignition the gold weighed 0·0495 gramme, or nearly $\frac{1}{4}$ of the quantity contained in the liquid.

These experiments do not cover the entire field of inquiry upon the subject, but they seem to indicate a parallel physical and chemical action, the former depending upon the surface and capillary condition of the charcoal, lampblack not acting physically at all, the latter depending upon a combustion of carbon into carbon dioxide.

University of Pennsylvania, March, 1882.

Book Notices.

PRACTICAL HINTS ON MILL BUILDING. By R. James Abernathey, Moline, Ill. London, Eng., 1880. 8vo.

This treatise, though general in name, is confined to flour milling, commencing with reminiscences of the older modes, which, if very slow, were certainly in several respects safer than the later and improved processes. The art of flour milling is much indebted to Oliver Evans for various improvements; if his plans were simple and crude they gave a new life to the antique style of grinding grain which seemed to have slumbered for ages. In those olden times—truly the palmy days of the millwright—everything which could be so constructed, was made of wood—penstock, waterwheel, windwheel, horizontal and upright main shafts, cogwheels, pinions and pullies, while belting was almost unknown. Several interesting extracts are given from the *Millwrights' Guide*, written by Oliver Evans, a work, the existence of which is probably unknown to many of our readers.

For unpracticed mechanics, Mr. Abernathey furnishes simple and useful general directions for arranging shafting and cogwheels, all iron or having wooden teeth, pullies, the ironing, setting and balancing of stones, making curbs, elevators, spouting, etc. The proper modes and machines for cleaning wheat, remedying specks in flour, the making, speed and clothing of bolting reels, etc., are also concisely explained. While mentioning the various kinds of shafting and cogwheels, the author remarks that the main upright shaft "is a nuisance anyhow," even if properly set, which is a rare case. He at the same time speaks more favorably of hard-wood boxes for shafting than might have been expected from a mill treatise of recent date. He devotes considerable attention to turbines; states that overshot, breast, or undershot waterwheels are now rarely introduced, and he prefers not to discuss the steam engine as a mill-motor, but to leave that to machinists.

An important portion of the volume comprises directions and detailed tables in regard to the pitch and speed of cogwheels, and the velocity and width of single leather belts for certain amounts of power. The author "does not assume to know" whether rubber belts will transmit as much power as those made of leather, but "would risk either"—though preferring leather. This is a mode of writing rather

too indefinite, for one who ought to know that there is much more tendency in rubber belts to slip on pullies than is the case with leather; independent of any other disadvantage. There are also tables appended for the thickness of shafts required for power named.

The second part of this book is the most important, treating of the furrowing of buhrs, middlings-purifiers, the new roller process, gradual reduction, and the Hungarian milling system. There are many valuable facts here set forth, in concise language, accompanied by plates and diagrams, in the text, of the various newer flouring machines and arrangements (with some omissions, however), different forms of rollers, etc. There are, in addition, valuable information and data, too numerous to mention, relating to other subjects connected with flouring mills. Mr. Abernathey gives excellent advice for the management of steam boilers, chiefly with the view to avoid their explosion; but he scarcely alludes to the great danger from explosion of flour-dust, or to the general increase of the fire-risk of flouring mills during the past few years. Notice of the best means of prevention and protection against such danger would have been undoubtedly acceptable. The work may be designated as practical, but not exhaustive. S. H. N.

TEXT-BOOK OF EXPERIMENTAL ORGANIC CHEMISTRY. By H. Chapman Jones. D. Van Nostrand. New York: 1881.

This little book, which is intended more as a guide to laboratory experiments than as a text-book for the classroom, appears to fulfill a want in this direction in a satisfactory manner. The student is led through an easy and simple course of experiments, such as will give him an insight into some of the beauties of organic chemistry. The experiments to be performed are clearly described and explained, and the text is written in an interesting, but strictly scientific style. We feel sure that many students will enjoy and profit by a careful study of the book. R. H.

SEWER GASES, THEIR NATURE AND ORIGIN; AND HOW TO PROTECT OUR DWELLINGS. By Adolfo de Varona, M.D. Second Edition, Revised and Enlarged. D. Van Nostrand. New York: 1882.

This little book can scarcely claim any originality either in facts or in treatment of the subjects presented. Yet short, unpretentious, popular essays on sanitary subjects, published in the cheap form, now

becoming more common, are an important means of arousing the people to some degree of attention to the avoidable causes of disease and the proper way of preventing them.

Although the author appears to consider the first part of the book, which treats of sewer gas and sewerage, as the most important, he is evidently much better acquainted with the subjects of ventilation and disinfection which are considered in the latter part, and he would, perhaps, have been wiser to have confined his essay entirely to these.

We will merely allude to the rather numerous errors, both in statement and in orthography, to be found in the first part of the book. There are not a few statements in regard to the composition and nature of sewer gas which a chemist certainly cannot endorse, several of which are also quite contradictory. While considerable correct information is given in this book, we must consider it on the whole rather unsatisfactory as a Science Primer. R. H.

REPORT OF THE CHIEF SIGNAL OFFICER FOR THE YEAR 1881.

The annual report of the Chief Signal Officer of the U. S. Army, to the Secretary of War, shows that both in the Military and in the Meteorological department there has been a steady and healthy growth, the equipments in all branches having been improved by additions which have been suggested by study and experience. In order to bring the service into active sympathy and co-operation with the ablest scientific institutions, the National Academy of Sciences has appointed an advisory committee of specialists. A permanent school of instruction has been established at Fort Meyer, in order to qualify the corps of observers in the duties of every department, and to raise the standard of service. The work has been more thoroughly systematized. New instructions for observers and improved forms for recording and preserving Meteorological data have been prepared. There has been a gradual extension and increase in the variety of forecasts, for the benefit of the various agricultural, manufacturing and commercial interests in all parts of the Union, with special forecasts of hot and cold waves, "northers," frosts, floods and ice-gorges. Important investigations of thermometric and barometric standards have been made, new constants computed and new tables constructed. Arrangements have been made for original investigations of atmospheric electricity, wind-force and solar energy, and for co-operation in the solution

of important physical problems. Two expeditions have been equipped for the Arctic regions, to share in the work marked out by the International conference. A system of stations has been established in Alaska, and arrangements have been made for organizing weather services for the Pacific coast and for separate States. The telegraphic service has been increased by a value of more than $34,000 per annum, without any additional cost to the government, and there is a prospect of further economy which will yield an additional reduction of $75,000.

This is only a partial enumeration of the subjects which have claimed the attention of the Bureau, but it is sufficient to show that our country is still without a rival in the variety, amount and practical advantages of its Weather Service. C.

INCANDESCENT ELECTRIC LIGHTS, with Particular Reference to the Edison's Lamps at the Paris Exposition. By Compte Th. du Moncel and Wm. Henry Preece. To which is added "The Economy of the Electric Light by Incandescence," by John H. Howell; and on the "Steadiness of the Electric Current," by C. W. Siemens. New York: D. Van Nostrand. 1882.

No. 57 of Van Nostrand's Science Series, on Incandescent Electric Lighting, is received, and, like most of its predecessors, is filled with interesting matter on the subject in hand.

In this little book the question is discussed by four different authors. Two of these, Mr. Siemens and Mr. Howell, bring their figures and experiments with them to justify their work and make good their assertions. The other two give good descriptions, in rose-color, of what they hope for the light rather than what has been fully demonstrated. The only feature that detracts from it, as a scientific paper, is a faint suspicion of an advertisement, and even with this it is a welcome addition to our electrical literature. Especially is this the case with the articles of Messrs. Siemens and Howell. The former giving the results of his experiments in the duplicate winding of coils for field magnets. These results are tabulated, so as to show, in compact form, the efficiency of the new system as compared with the old. And the latter giving his conclusions as to the cost of incandescent electric lighting, and showing the methods adopted to arrive at those conclusions. Both of these papers have been prepared with much care, and fully merit the consideration which they will undoubtedly receive.

Mr. Siemens demonstrates the possibility of increasing the efficiency of the dynamo machine from 45 to 53 per cent., a most desirable attainment; and when to this is added the greater steadiness of the current produced we see the value of the line of improvement which these experiments suggest. It may be said that the arc lamp should be so constructed as to present at all times an unvarying resistance, and that then the work of the dynamo would be uniform and currents regular in the present form of machine. Unfortunately, however, this is not the case. They have not been so made, and until they are the present relief from current fluctuations will be highly appreciated by those interested in electric lighting.

It is but fair to say, however, that Mr. Siemens' experiments were made with a comparatively small machine, and that the resistances in the outer circuit presented only slight fluctuations. What the result would be in a long circuit—such, for instance, as a Brush circuit—of forty arc lamps, where the resistance varies, say from 80 ohms, when all the lamps are drawing full arc, down to 40, when a large number of lamps feed simultaneously, can only be conjectured.

In Mr. Howell's paper we have the result of the investigations of an unbiased expert on whose figures we can rely, and if we find that after computing interest on plant, cost of maintenance, attendance, etc., there is still a margin left under the cost of gas, we can safely engage in incandescent lighting. Unfortunately, however, his figures are not reassuring. Where the necessary power is already employed during the day, for other purposes, it may be feasible. But where the power must be supplied on purpose it is very doubtful if even at ten lights of 16-candle power, per HP consumed, the operation would be satisfactory, financially. Much less would it be so with the number dropping down to six or seven per horse-power.

With the system worked up so completely, and all the appliances supplied for making it convenient and ornamental, it seems a pity that the cost of the power to produce it should debar us from its use, and it is to be hoped that the thumb-screw of invention can be so applied to some other part of nature's organism as to extort a power sufficiently cheap to make this admirable system a practical success.

N. H. E.

AN INSTRUMENT FOR ELECTRO-MASSAGE.

At the last stated meeting of the Institute the Secretary, among other novelties, exhibited and described the ingenious Electro-massage instrument of Dr. John Butler, of New York, the appearance of which is shown in the accompanying illustration.

The object sought to be accomplished by this invention is to combine, by the use of one instrument, the several operations of massage (manipulation, or friction by the hands on the limbs and joints) and electrization; for as both of these procedures are found necessary or advantageous in certain muscular, articular and nervous disorders, and are usually applied successively, often to the great fatigue and discomfort of the person operated on, the desirability of devising an apparatus by which these two procedures would be accomplished at once is obvious.

The inventor of this apparatus, in watching the operation of

manipulation, conceived the idea that if the mechanical motion used in rubbing the patient could be made to generate an electrical current, which should be transmitted to the affected part while it was being manipulated, the requirements of the case would be met. Following out his idea, he devised the instrument here referred to, which appears to answer its intended purpose very well.

The instrument, as will be understood by consulting the accompanying cut, consists of a hollow metallic roller, covered with chamois leather, an electro-magnet, and a permanent magnet, the whole set in a strong frame, which holds it together. The roller acts on one of the electrodes, and is likewise the driving piston of the apparatus, communicating its motion, by means of connected gearing, to the electro-magnet, causing the poles of the latter to revolve opposite to those of the permanent magnet. The rounded portion of the latter, which is

flared for greater convenience, forms the handle by which the instrument is moved to and fro over the part of the body to be treated.

The proportions of the gearing are such that each revolution of the roller causes the electro-magnet to make twenty-five revolutions. The current thus induced is interrupted at each revolution by a break-piece. The instrument gives a current sufficiently strong for the purposes for which it is intended to be used.

To complete the circuit a flexible metallic disk, likewise covered with chamois, is connected through an insulated wire to the binding post shown in the cut.

In using the apparatus both electrodes are moistened to increase their conducting power, the hollow roller being filled with warm water to render its application agreeable, and both are brought in contact with the body of the patient. As the moistened roller is moved with gentle or vigorous pressure, as the case may require, over the surface of the body, the current is transmitted, by the apparatus, through the part over which the roller is caused to move. By shifting the position of the armature of the permanent magnet the strength of the current can be regulated at will.

RECENT IMPROVEMENTS IN THE MECHANIC ARTS.

LIGHTING GAS BY ELECTRICITY.—A novel electric gas-lighter consists of two positively operated movable electrodes arranged to meet over the gas-orifice and then recede out of reach of the flame. They are operated by the turning on and off of the gas, by the ordinary horizontal cock of the gas-burner. One of the electrodes is rigidly secured to the rear end of the cock-spindle and is carried by the rotation of the latter through a vertical arc past the side of the burner. The other electrode is pivoted, near its lower end, to the side of the burner, and provided with a sector-pinion which engages with a similar pinion formed on the forward end of the cock, so that the motion of the cock will cause the latter electrode to be moved in the same manner as the former. The arrangement is such that the two electrodes move in opposite directions, passing each other when in line with the gas outlet, and falling back in opposite directions out of the flame. Small projecting fingers of platinum are secured to the ends of the electrodes and pass each other with a frictional contact, whereby the production of the electric spark is insured.

SELF-PROPELLING TORPEDOES.—In the recent experiments with the Lay torpedo, at the U. S. Government torpedo-station at Newport, R. I., a grave difficulty was encountered, in that the tendency of the liquid carbonic acid gas—which is used as the motive force for driving the torpedo—was to freeze, when suddenly expanded by being drawn off from the reservoir or flask for use. Artificial heat was, for a time, used to counteract this tendency of the liquefied gas to congeal when drawn from the flask, but with unsatisfactory results. It remained, however, for a retired physician of Hartford to happily solve this apparently insurmountable difficulty by the discovery of the fact that there was sufficient latent caloric in the sea-water, in which the torpedo-boat itself was immersed, to supply the heat necessary to prevent the congelation of the gas when expanding in the pipes between the flask and the engine. This was accomplished by running the connecting pipes between the flask and engine on the outside of the torpedo-boat, in direct contact with the sea-water.

MECHANICAL TELEPHONE.—This recent improvement provides a means—without the employment of a battery—for transmitting and reproducing sounds, loud, clear and distinct, at short or long distances as may be desired. It consists of a simple helix surrounding a soft-iron core, having no magnetic connection, and acted upon by a thin strip of iron connected with the north or south pole of one or more magnets. This strip vibrates in unison with the transmitting or receiving diaphragm by means of a felt cushion or other connecting medium. This construction, it is said, constitutes a magneto-electric machine or generator, whereby the voice itself produces the electric current by which the sounds are transmitted to and reproduced by a similar or corresponding instrument at the other end of the line, there being no current in the helix or on the line, excepting that so produced, and no other magnetism in the soft-iron core inside the former.

NEW ENGINE GOVERNOR.—The object of this improvement is to provide a governor for steam engines that will not require a change in the speed of the engine in order to bring about a change in the amount of steam admitted to the cylinder. It consists in the interposition, between the piston and the crank of any engine, of a hydraulic cushion which shall receive compression by the transmission of power through it to the crank. This compression is utilized to actuate the cut-off gear or throttle-valve.

NEW METHOD OF OPERATING TELEPHONE EXCHANGE APPARATUS.—Two or more automatic switches are provided, each constructed to allow any subscriber connected thereto to automatically connect his line with any other line upon the same automatic switch, and a line or lines from each automatic switch to a common manual switch. Suitable apparatus is provided at the manual switch for operating the automatic switches. This arrangemement enables any subscriber to connect his line either to any other subscriber's line of his automatic section, or to a line leading to the manual switch for connecting the subscriber's line with any other line-connection upon the manual switch.

VALVE-GEAR FOR STEAM ENGINES.—This improvement in valve-gear comprises a steam or other engine employing a slide-valve and the usual inlet and exhaust ports, in which the valve has a stroke equal in length to that of the piston, and the longest axis of the port-opening under the valve is in the plane of the travel of the valve.

Washington, D. C. F. B. BROCK.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

As we go to press, the American Society of Mechanical Engineers is holding its first regular meeting of the current year, in the Hall of the Institute, under the presidency of Prof. Robert H. Thurston, of the Stevens Institute. The meeting is fully attended and, from the number and character of the professional papers to be presented, promises to be the most important meeting which this young but flourishing Society has held. The programme provides for a session of three days from Wednesday, the 19th, to Friday, the 21st of April, inclusive.

For the first day's session, the programme provides for general business, professional papers and discussion in the morning and, for the afternoon, a memorial service in honor of the late ALEXANDER L. HOLLEY. Mr. James C. Bayles is named to pronounce a eulogium upon the deceased. In the evening, the Society is invited to a reception, in its honor, in the Academy of Fine Arts, by the citizens of Philadelphia.

The programme for the second day embraces an excursion on the Delaware river in the morning, with visits to such places of professional interest as the League Island Navy Yard, the grain elevators,

Wm. Cramp & Sons' shipyard, John Roach & Son's shipyard, etc. The evening is devoted to a subscription dinner at Horticultural Hall.

The third day's programme provides for strictly professional business, at morning, afternoon and evening sessions.

CORRESPONDENCE.

The following correspondence respecting the Panama Canal, received by the Secretary for presentation at the monthly meeting of the Institute, by courtesy of Prof. J. E. Nourse, may have some interest to many of the readers of the JOURNAL. W.

U. S. STEAMER "VANDALIA,"
HAVANA, CUBA, *March 1, 1882.*

HON. W. HUNT,
Sec'y Navy, Washington.

SIR:—It may be interesting to the Department to learn the results of my personal observations on the Isthmus of Panama, and of the changes that have occurred since my last visit eleven months ago.

The Canal Company has quietly been at work, preparing for the gigantic task before it. It has accomplished a large amount of work which I should term "surface" or preliminary work. Several of the best officers of the company have died since my last visit: notably, Messrs. Blanchet, Bionne and Sharpe, the latter Superintendent at Gatun. None of these gentlemen died of yellow fever, as reported. Messrs. Bionne and Blanchet died of the local fever of the country, want of suitable attention, and overwork and neglect of themselves. I heard it said here that Sharpe committed suicide; whether this is true or not I do not know.

A number of deaths among the inferior employees have occurred, but the number has been greatly exaggerated in the American newspapers. Of course a number of the white employees have been ill with Calentura, but the death rate has not been exceptionally great; which I consider remarkable, as my personal observation is that the French employees take little or no care of themselves, and eat and drink just as if they were at home in France, and poison themselves with vast quantities of absinthe.

I crossed the road to Panama, and with Mr. Alfred Razy, in charge of the works at Aspinwall, visited the proposed axis of the Canal near the Rio Mindi. I saw enough to convince me that, notwithstanding the reports to the contrary, a large amount of valuable work has been accomplished.

Whether as much has been done as would have been done had American engineers superintended, I cannot say. My own belief is that our people would have accomplished more and spent more money. The French engineers will work in their own way and take their own time. I am told that nothing important is done until it is sanctioned by the great minds in Europe. The work progresses steadily, but a work so gigantic as this Inter-oceanic Canal needs cautious work and careful expenditure of money at first, until the final plans and lines are well determined. The entire route has been cleared of trees and underbrush for a width of 300 yards. This is a work of no small magnitude in itself. Fifty miles of undergrowth cleared off in this region represents a deal of work. The trees and undergrowth have been partially burned off, and will probably all be burned off before the season ends; for, if left, the vegetation here is marvelously rapid and much of the work would have to be gone over again.

All along the line the Company has constructed stations and villages for its laborers; at Gatun these works are of an elaborate character. I think more money has been spent than is necessary for grading. Sidings and narrow-gauge rail tracks are also constructed to carry off the earth taken up by the excavators, which earth is to be dumped into the marsh near Boca-Chica, so as to be the foundation of a town.

The machinery brought from Europe is clumsy and comparatively antiquated, and I hear that much of the machinery will be made in the United States. A sub-contract with Messrs. Sleven & Co., of San Francisco, to commence excavating between the Mindi and Gatun, is reported.

Messrs. Razy and Hull, the officers of the Canal, were exceedingly polite to myself and officers, and offered every facility.

I am, sir, very respectfully, your obedient servant,

(Signed) R. W. MEADE,
Captain U. S. N.

A Long Span of Wire.—The longest span of wire in the world is used for a telegraph in India, over the River Kistnah, between Bezorah and Sectanagrum. It is more than 6000 feet long and is stretched between two hills, each of which has a height of 1200 feet. The only apparatus that was used for stretching the wire was a common anchor capstan.—*Der Techniker.*

Vienna Metropolitan Railway.—This enterprise will require an expenditure of about 12,000,000 francs ($2,400,000). The track will be principally laid upon elegant and solid viaducts and a part in tunnels. The funds are furnished by an English company, the works being directed by English engineers. After examining various systems in the United States, Germany, England and France the company has adopted Francq's French locomotive. Thus, while the French waste their time in discussions of various methods for relieving the crowded traffic of streets, other nations profit by their inventions and discoveries. The French invent, study and discuss, adding plan to plan and device to device, their neighbors act.—*Les Mondes.*

Electric Metallurgy.—Electricity is still too dear to be extensively employed in the mechanic arts, but it can be advantageously substituted for coal and heat in the reduction of zinc ores. The ordinary processes require an expenditure of about 70 or 80 francs ($14.00 or $16.00) per ton. Electricity may be employed in three different methods, which differ chiefly in the nature of the acid which is employed as a solvent. The ores do not require much preparation, the calamine need not be calcined and it is not even necessary to separate the lead or the calcareous gangues. The ores are placed in great basins, after being treated with sulphuric acid, where the sulphate of zinc is dissolved in water. The liquid passes through a series of basins where it deposits, in a metallic state, under the action of electricity, a part of its zinc and the liberated acid is used upon new supplies of ore. The lead, silver and other insoluble matters are collected in the residue and the iron, which is precipitated upon the lead anode, falls to the bottom of the basin. If the electricity is produced by steam power, the quantity of coal which is required for a given amount of zinc is almost precisely the same as would be required for the same amount of ore in the old methods. The treatment can be conducted at the mine, thus avoiding much of the expense of transportation. The plant is only about half as great as in distillation.—*Chron. Industr.*

Improved Mortar.—Sawdust is better than hair in protecting rough cast from peeling and scaling under the influence of frost and weather. The sawdust should be first dried and then thoroughly sifted, in order to remove the coarser particles. A mixture is then made of two parts sawdust, five parts sharp sand and one part cement, which should be thoroughly stirred together and then incorporated with two parts of lime.—*Der Techniker.* C.

Variations in the Velocity of Sound.—Prof. Mach, of the University of Prague, has experimented with sounds which are produced by electric sparks. The waves which are excited by two simultaneous sparks interfere, and the interferences are observed by the traces which they leave upon glass covered with lamp black. The velocity of wave propagation is greater than that of ordinary sound waves, but it diminishes in proportion as the waves separate from the point of excitement and tends towards the ordinary values.—*Soc. de Physique.* C.

Ocean Meteorology.—The study of ocean meteorology, which was first successfully undertaken by Lieut. Maury, has been greatly extended in France by M. Brault. His investigations were begun in 1869, upon the basis of exclusively French documents, and they were so successful that, in 1878, he received a prize from the French Exposition. His charts of the North Atlantic appeared in 1875 and were presented to the French Academy on the 6th of September. They contain 230,000 observations, both of the direction and of the intensity of the wind. The charts of the South Atlantic appeared in 1876, and those of the Indian and Pacific oceans in 1880. They contain 1,820,000 observations. One of these charts is especially noticeable, that of the summer isanemones or curves of equal wind-velocity. They are almost identical with the curve of mean isobars or mean atmospheric pressure. They introduce, for the first time, considerations of the force of the wind at the surface of the ocean, and throw light upon such points as the succession of winds, the ocean currents, the rainfall, the state of the sky and sea, the proportion of tempests and all the principal elements of nautical meteorology. — *Les Mondes.* C.

Introduction of the DuPuy System into Spain.—A successful trial of DuPuy's method of obtaining soft iron directly from the ore has been lately made in England, in the establishment of Lord Dudley, at Round Oak. It was witnessed by a Spanish engineer, representing one of the largest national works, with a view of introducing the system into Spain. It is expected that its introduction will be of great advantage to the iron industries of the Peninsula and that it will thoroughly supplant the old and barbarous methods of hand-puddling.—*Gaceto Industrial.* C.

Ventilation of the Mont Cenis Tunnel.—M. F. de Kossuth, Director-General of the mines of Cesena, has made a special study of the subject of artificial ventilation, in order to devise some remedy for the insufficient supply of air in the tunnel of Mont Cenis. His examination embraces the quantity of air required for good ventilation, examples of mines in which a sufficient supply is introduced by mechanical means, the laws of ventilation in subterranean galleries, the facilities for automatic ventilation, the quantities of injurious gas developed in the tunnel, the quantities which are required to dilute the deleterious gases produced by combustion in the locomotives, the time in which the air of the tunnel would become asphyxiating if ventilation ceased, the inconvenience of the measures which are now employed, and a demonstration of the efficacy of the plan which he proposes. He finds that 84 cubic metres (109·874 cubic yards) per second would be required and that it could be supplied by 224 horse-power. There is already a canal at Bardonnèche which supplies 800 litres (211·36 gallons) per second, with a fall of 42 metres (45·93 yards), which would yield a force of 448 horse-power. This force can be obtained without other cost than is required to maintain the necessary repairs.—*Ann. des Mines.* C.

Phosphor-Bronze Wire.—The experiments of Nystrom and Rothen show that phosphor-bronze wires have an electric conductibility about one-fifth as great as that of copper or one and a half times as great as that of iron. Bede has found that one kilometre (1093·633 yards) of phosphor-bronze wire, 2 millimetres (·0787 inch) in diameter, has a resistance of 28 ohms, while an iron wire of the same dimensions has a resistance of 40 ohms. A wire which is well hard-

ened at the drawing-plate has a tensile strength of 120 kilogrammes (264·55 pounds) per square millimetre and stretches only about one per cent. before breaking. A wire which is properly annealed stretches about 60 per cent., but the tensile strength is only about 40 kilogrammes per square millimetre. The rupture of a telegraphic or telephonic wire may cause accidents to men or houses in cities. Bede has shown that when a wire of phosphor-bronze breaks its elasticity brings the fragments towards the neighboring supports before they have time to do any injury. In Brussels a large number of telephonic lines been supplied with phosphor-bronze wires of $\frac{8}{10}$ millimetre (·0315 inch) in diameter. In Ghent nearly the whole telephonic network is laid with the same wires. This small diameter can be employed because the resistance of the wire to oxidation secures its durability. —*Ingen. Conseil.* C.

Electric Current Produced by Light.—M. P. Laur reports the following experiment. In a small dark chamber, with a movable shutter, a glass vessel with plain sides is placed, in which he pours a solution of 100 parts water, 15 parts common salt, 7 parts sulphate of copper; a porous vase filled with mercury is placed in this solution; two electrodes, one formed by a plate of platinum, another by a plate of sulphuret of silver, are inserted, the first into the mercury, the second into a cupric solution; these two electrodes are connected with a galvanometer, the apparatus is placed in the sun and the dark chamber shut; as soon as the circuit is closed the galvanometer needle turns in a direction which shows that the silver sulphuret is positive; when the needle comes to rest the shutter is opened and the needle is immediately repelled, soon coming to a new position of equilibrium; on closing the shutter again the needle slowly retrogrades towards its first position. When the needle is placed in the open air, if a cloud passes before the sun the movements of the needle show the variations of luminous intensity. The movements are attributed to the reduction of the silver sulphuret by the cupric proto-chloride, a reduction which takes place only under the action of the sun's rays. Similar photo-electric currents may be produced by other combinations of electrodes.—*Comptes Rendus.* C.

Repeating Piano.—In the French Electrical Exposition, J. Carpantier exhibited a repeating electrical apparatus which he called a Melograph. It is connected with a harmonium some yards distant, the keys of which are electrically connected with punches in the Melograph; these punches, when the electrical connection is completed, pierce a band of paper in accordance with the notes which are played. When the band is prepared, the Melograph can react upon the harmonium, making it repeat the air as often as may be desired. The inventor hopes to improve his instrument so as to give satisfactory reproductions of the most intricate improvisations.—*Chron. Industr.* C.

Restoration of Architectural Structures.—T. V. Parravicini severely criticizes the rage of restoration which has prevailed so largely during the last half-century. While much good may have resulted from the minute investigations and profound architectural studies to which they have given rise, he fears that, if the buildings continue to be treated as they have been, our grandchildren will be unable to form any idea of their original beauty. In many cases more has been done for the destruction of noble monuments of art than had been accomplished in the preceding ages of ignorance, barbarism and devastation. When the strange and fatal idea of restoration first arose, monumental archæology was still in its infancy and had not learned that the historic and artistic importance of a building depends wholly upon the authenticity of its various parts. The idea of the restorer implies the possibility of taking from a monument some part of its life, with the sole object of representing in the building the best times in its history, or giving it a unity of style which it never had, without any other guide than individual caprice. In past ages any suspicion of falsification was removed by the fact that builders had no knowledge of preceding styles; hence, when any repairs or changes were made, they necessarily followed the fashions of the time and thus maintained a truthfulness which should always characterize the highest excellence in art.—*Il Politecnico.* C.